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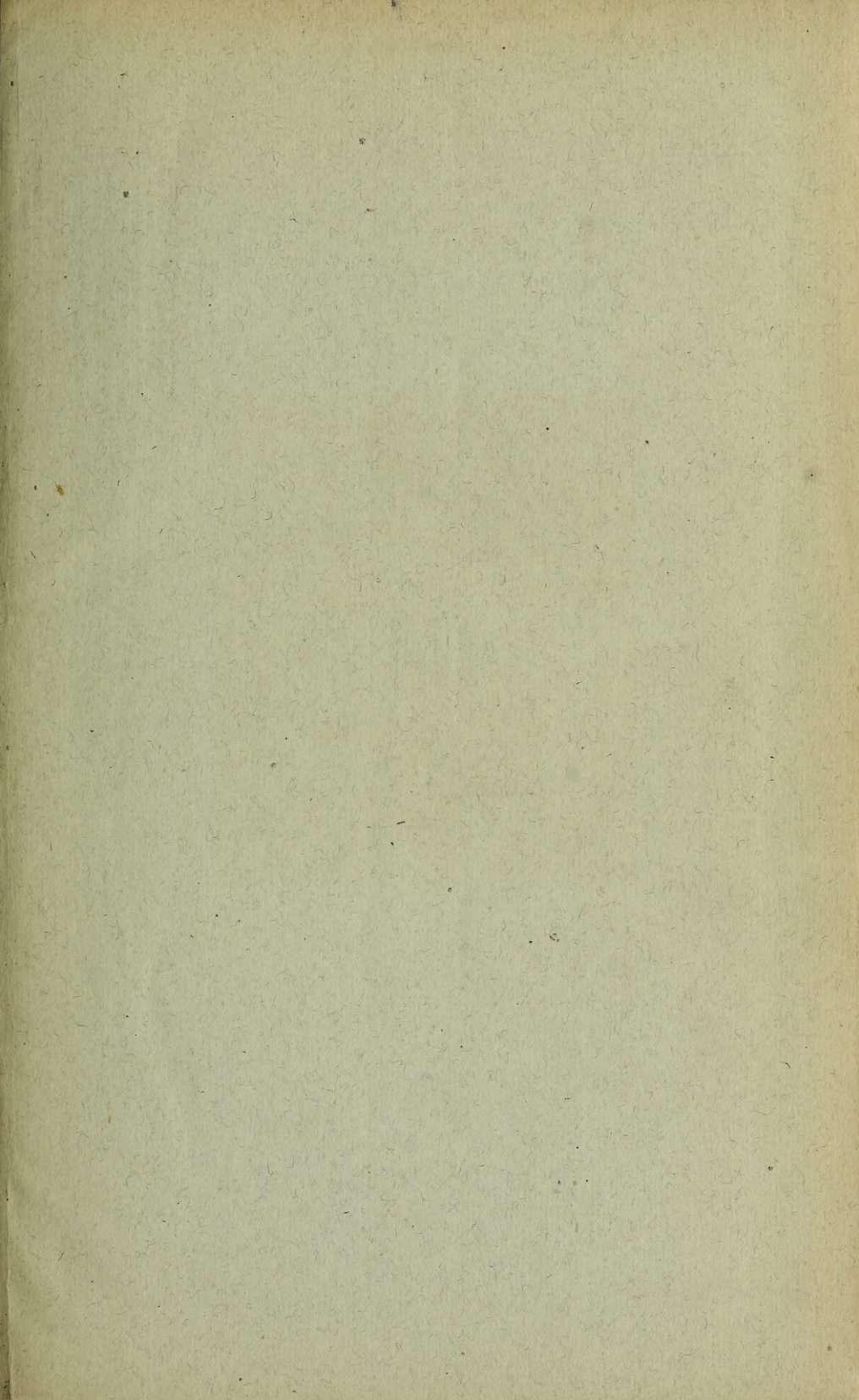
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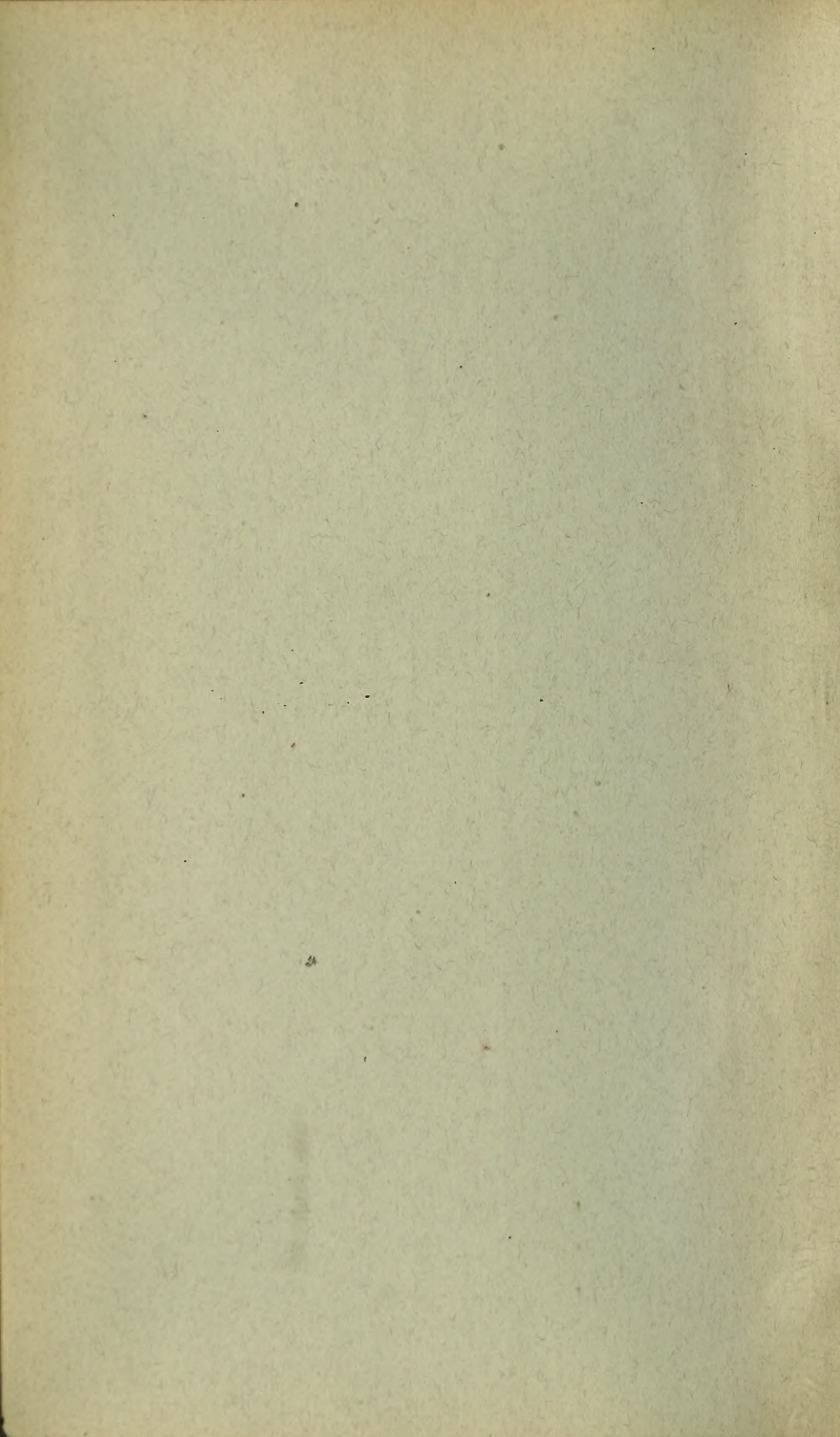
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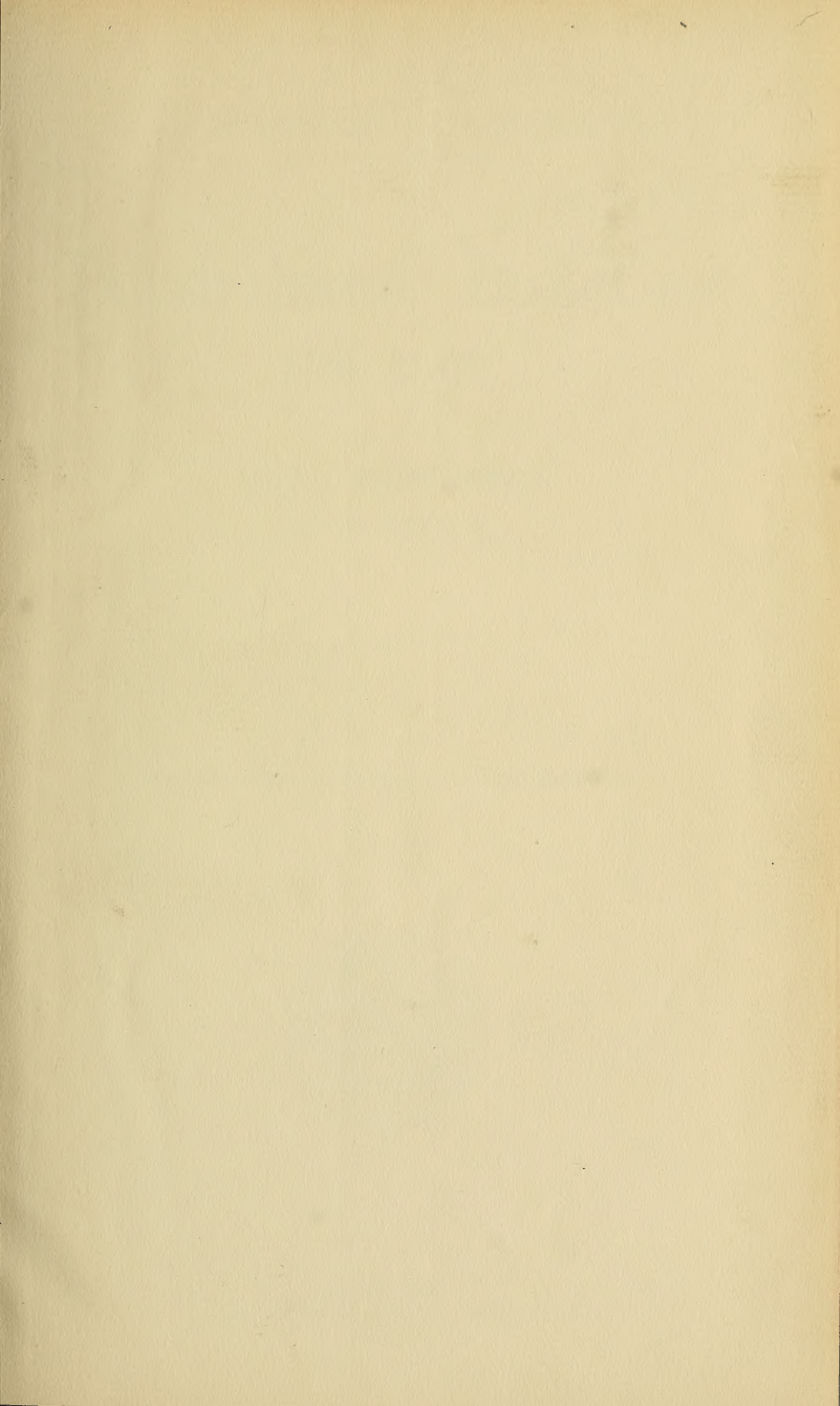
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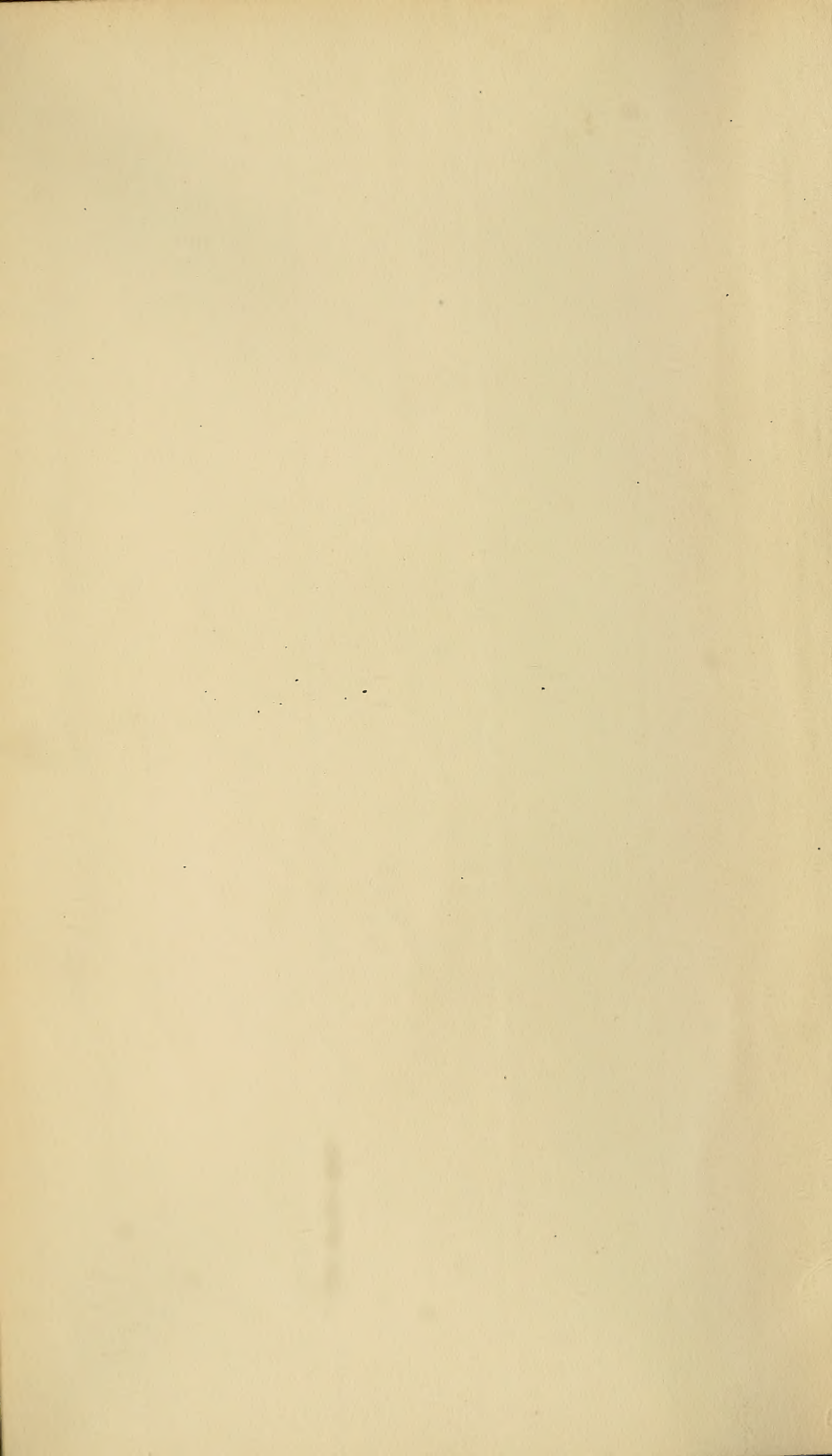
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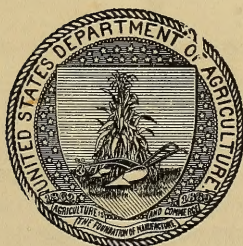
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U.S. DEPARTMENT OF AGRICULTURE
OFFICE OF THE CHIEF OF BUREAU OF PLANT INDUSTRY
WASHINGTON, D.C.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 51



Contribution from the Bureau of Chemistry, Carl L. Alsberg, Chief.

July 20, 1914.

(PROFESSIONAL PAPER.)

A BACTERIOLOGICAL AND CHEMICAL STUDY OF COMMERCIAL EGGS IN THE PRODUCING DIS- TRICTS OF THE CENTRAL WEST.¹

Under the direction of M. E. PENNINGTON, *Chief, Food Research Laboratory*,
associated with M. K. JENKINS, E. Q. ST. JOHN, and W. B. HICKS.

INTRODUCTION.

The deterioration of eggs between the time of their production on the farm and their arrival at the consumer's table has been discussed from different viewpoints in the publications of the Department of Agriculture. Among these discussions have been the various causes contributing to the loss of freshness, the necessity for lessening the number of eggs that become totally unfit for food each year, the results of improved methods of handling, and the fixing of responsibility for the enormous economic and financial loss due to decay.

The scientific literature on the bacteriology and chemistry of the egg of the domestic fowl is surprisingly meager, considering the many ages that the egg has served as an important article of food. The distinction between a good and a bad egg has rested more often on individual opinion, colored by prejudice or preference, than upon

¹ This report embodies a study of eggs, the first of a series of reports from the investigation of frozen and dried eggs, which is being conducted by the Food Research Laboratory of the Bureau of Chemistry. It deals with the subject of the quality of the eggs which go to the egg-breaking establishments in the egg-producing sections of the Central West. It is the basis on which the study of industrial problems and conditions must be founded. The second report of the series will deal with the commercial procedures in the packing houses, the environment, and methods of work which must be followed if a high-quality product is to be produced. Other phases of the investigation will be embodied in reports on the general management in the packing houses making for efficiency, and on the treatment which the output receives in the establishments of the bakers, who are the chief users of frozen and dried eggs. For the data submitted we are indebted to M. K. Jenkins, who has studied a number of individual eggs, prepared the "commercial" samples, and has been of very material assistance in the correlating and presenting of the facts; to E. Q. St. John, who has done the greater part of the bacteriological work; and to W. B. Hicks, who is chiefly responsible for the chemical analyses. The Omaha Food and Drug Inspection Laboratory, with its force of chemists, in charge of S. H. Ross, was assigned to this investigation with the staff of the Food Research Laboratory for the summers of 1911 and 1912, and was made the headquarters for the field investigations.

NOTE.—This bulletin gives details of an extensive study of commercial eggs and makes recommendations for improvements in handling. While the study was made in the Central West, the bulletin is equally of interest to all sections where eggs are produced in commercial quantities and are sent to egg-breaking or other packing establishments.

the exact knowledge of the composition or history of the egg itself. The farmer's wife, accustomed to the fresh eggs of the farm, discards as unfit for food an egg which the city baker would, with a clear conscience, serve to his own family. The difference in the point of view has progressed even to the savants who have held opposite and positive opinions concerning the wholesomeness or desirability of certain eggs, especially of those known in commerce as "frozen" or "desiccated."

Investigation has shown that when the egg is laid it is of a fairly constant chemical composition and contains but few bacteria or molds. In the vicissitudes of marketing, with its attendant undesirable conditions, eggs in the shell undergo a variety of changes, referable, almost exclusively, to the mode of handling. These changes, their effect upon the food and market value of the egg, and the means by which they can be reduced to a minimum have been, and still are, a subject of investigation by the Department of Agriculture cooperatively with every branch of the egg-marketing industry.

The great variety of conditions to which an egg is subjected and its sensibility to temperature, humidity, odors, etc., result in many evidences of deterioration in the eggs on the market. The extent to which such downward changes are reflected in the composition of the egg, together with their recognition by physical, chemical, and bacteriologic methods, is the subject of the present report.

The work has been done as part of an investigation of the preparation of frozen and dried eggs. It is the foundation on which to build all the other phases of the investigation, such as the construction of the apartments in which egg breaking for food purposes can proceed; the methods used to guard against bacterial contamination; the systematic application by the employees in the packing houses of the knowledge gained by scientific research to increase accuracy and efficiency; the quality of the output of the houses under old and new conditions, and the behavior of those products when they reach the hands of the baker, who, for this investigation, may represent the consumer. These diverse parts of the work will be reported in a series of publications of which this is the first. It will be observed, therefore, that the subject is discussed from the industrial viewpoint, even though it is essentially a laboratory study.

The individual eggs, and some of the composite egg samples, were opened in the laboratory; the samples designated "commercial" were opened by a bacteriologist in packing houses where the surroundings were as clean as, or cleaner than, in the laboratory and where all utensils were sterilized.

The information given in this report has been gathered in southwestern Iowa, northern Tennessee, and the valley of the Missouri from the northern border of Iowa to the central part of Kansas.

The eggs were from sources comparatively close to the investigators; that is, the haul was seldom more than 200 miles. Had the eggs not been broken at these first, or, at most, second concentrating centers, the probability is that they would have been shipped a four to seven days' haul before reaching a consuming center. They were, therefore, in a correspondingly better condition because broken nearer their point of origin. The field work reported was carried on during the summers of 1911, when exceptionally hot weather prevailed over an unusually wide territory, and 1912, which was not an unusual summer in any respect. The individual eggs, however, were studied between the winter of 1910 and the autumn of 1912.

To comprehend the egg on the market it is necessary to determine first the condition of the absolutely fresh egg, that a standard of comparison may be obtained, and then the condition of the eggs on the market to see wherein and how much they differ from the fresh article. It is also highly desirable to observe the character of the eggs bought by the housewives at the corresponding time, in the same locality, to see whether there are any material differences between the eggs broken for home cookery and those broken by the egg canner who supplies the public baker.

FRESH EGGS.

BACTERIAL CONTENT.

The chemical and bacteriological characteristics of perfectly fresh eggs—that is, eggs which are not more than 24 hours old and which are kept in a cool place—have been given by the first author of this report in a previous communication, entitled “A Chemical and Bacteriological Study of Fresh Eggs.”¹ In this study 150 high-quality eggs, not more than 24 hours old, were examined for the bacterial content in white and yolk. A strictly fresh egg is pictured in Plate I (see at end of this bulletin). Aseptic precautions were used in obtaining samples and all the work was done on the basis of weight, not volume, since the latter introduces a decided error in so viscous a substance as egg. A summary of the results shows that there was found an average of 2 organisms per gram in the white and 6 per gram in the yolk when the incubation temperature was 37° C., and 7 organisms per gram in the white and 9 per gram in the yolk when the incubation was at 20° C. It may be said that these eggs were gathered between February and November, inclusive.

Stiles and Bates,² in a recent study of 616 fresh eggs gathered between April and October, found that the average infected yolk contained 271.7 organisms to the cubic centimeter and the infected white 15.9 organisms. They also found, however, that in 13.99 per

¹ J. Biol. Chem., 1910, 7 (2): 109.

² A Bacteriological Study of Shell, Frozen and Desiccated Eggs Made Under Laboratory Conditions. U. S. Dept. Agr., Bureau of Chemistry Bul. 158, 1912.

cent of the yolks examined there were no organisms present in 1 cc of the material, and the white of the egg was sterile in 1 cc quantities in 32.18 per cent of the samples examined. Maurer¹ reported 81.9 per cent of the eggs he examined to be sterile, and stated that of the 18.1 per cent infected 82 per cent were infected in the yolk, 25.9 in the white, and only 7.9 per cent in both yolk and white. Maurer used aseptic precautions in obtaining samples of the egg material examined. Stiles and Bates did not clean the shells, and their method of opening was to crack on the edge of a sterile Petri plate and shift the yolk from shell to shell in housewife fashion, to effect a separation of the two substances. The plate used for cracking the shell was also the container of the sample. Maurer does not give the number of organisms occurring, merely stating their presence or absence.

The bacterial content of fresh eggs has been proved to be widely diversified in the character of the organisms present, but their numbers are small. The varieties of organisms present will be considered elsewhere. It may be said, however, that Pennington² did not find *B. coli* in any of the 150 eggs examined; neither did Maurer in a study of 160 eggs, many of which had dirty shells or were placed under artificial conditions favoring shell penetration. *B. coli* were found on the shells in many cases. Stiles and Bates found one egg laid in the month of July that contained *B. coli* in the yolk. It is possible, however, that this might have been the result of contamination while cracking on the edge of the Petri dish or separating white and yolk by the shell method of the housewife. With the exception of this one egg yolk wherein *B. coli* were reported, the examinations of fresh eggs do not, from a practical industrial viewpoint, show conflicting testimony. They agree fairly well in asserting that the fresh, well-handled egg, though not always sterile, is not, on the other hand, infested by large numbers of bacteria, and *B. coli* are practically never present.

After bad handling or mistreatment the number of organisms may, and frequently does, increase enormously. Whether they invariably appear in numbers after bad handling or age has interfered with the integrity of some one or more of the component parts of the egg is a problem to be solved. The studies here chronicled are expected to throw some light on this question. Such studies would indicate also whether the large numbers of bacteria found in certain eggs are due to a rapid increase of the original organisms found in them even while still present in the oviduct, or whether an additional infection through the shell is common in the course of the usual routine of marketing.

¹ Bacteriological Studies on Eggs. Kansas State Agricultural College Bul. 180, 1911.

² J. Biol. Chem., 1910, 7 (2): 109.

CHEMICAL COMPOSITION.

Numerous chemical analyses of fresh eggs have been made in this laboratory in connection with the investigation of the handling of eggs. They extend our knowledge of the composition of the fresh egg, especially in relation to the quantity of loosely bound nitrogen in egg protein; that is, the nitrogen split by the action of a weak alkali and removed for estimation by aeration. This form of nitrogen occurs in very minute quantity in the protein of the freshly laid egg, and is much increased, though still small in amount, in eggs that have deteriorated. The amount of loosely bound nitrogen is at the present time the best and simplest index that has been found of the chemical stability of the egg. Hence the quantity of this substance has been determined in the various grades and kinds of market eggs and in those used by the egg breakers, as well as in eggs 24 hours old.

The analyses recorded in Table 1 show that most of the loosely bound nitrogen is found in the yolk of the egg, where it averages in western summer eggs of highest quality 0.0023 per cent. Whole eggs of like grade gave 0.0013 per cent as an average.

TABLE 1.—*Fresh eggs.*

Portion and sample No.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Gelatin liquefying organisms per gram.	Ammoniacal nitrogen, Folin method.		Moisture.	Ether extract.	Size of sample.
		20° C.	37° C.		Wet basis.	Dry basis.			
					Per cent.	Per cent.	Per cent.	Per cent.	Eggs.
White:	1911.								
261.....	July 14				0.0004	10.0033			18
271.....	July 17				.0003	.0025			12
557.....	Aug. 21				.0004	.0033			12
559.....	do				.0003	.0025			12
561.....	do				.0003	.0025			12
Yolk:									
214.....	July 10	150	360	130	.0026	.0050	47.81	31.87	6
260.....	July 14				.0025	.0047	46.88		18
270.....	July 17				.0023	.0043	46.89		12
556.....	Aug. 21				.0024	.0046	47.80		12
558.....	do				.0020	.0034	47.28		12
560.....	do				.0022	.0042	47.84		12
Whole egg:									
126.....	June 26	0	5				73.19	10.86	30
127.....	do	0	0				73.44	11.28	30
168.....	July 3	150	70				72.96	11.40	36
212.....	July 10	75	70		.0013	2.0047			6
262.....	July 14				.0011	.0040			
272.....	July 17				.0013	.0047			11
273.....	do		0						6
329.....	July 24	45	59		.0015	.0054			
330.....	do	85	45		.0013	.0047			
445.....	Aug. 4				.0011	.0040			24

¹ Moisture content of fresh egg white taken as 87.94 per cent, average of 236 eggs.

² Moisture content of fresh whole egg taken as 72.44 per cent, average of 9 eggs (analyses given in König, pp. 98 and 1470, and of three analyses Nos. 126, 127, and 168 given above).

A number of unpublished analyses of fresh eggs from various sources would indicate a maximum and minimum variation of 0.0010

and 0.0015 per cent nitrogen, respectively. The analyses of summer eggs made in the western egg-producing district are comparatively few, but since their composition proved to be like that of the eggs studied in the general egg-handling investigation it was not deemed necessary to multiply them beyond the number needed to confirm existing data.

The moisture content of the summer egg is of interest. It may be that there is a relation between the amount of water present in the egg and its resistance to decay. A study, in another connection, of perfectly fresh eggs from a well-cared-for flock during different seasons, when the fowls showed physiological variations, is given in Table 2.

TABLE 2.—*Water content of fresh eggs.*

Date.	Number of samples.	Individual eggs.	Moisture.	
			White.	Yolk.
			<i>Per cent.</i>	<i>Per cent.</i>
Feb. 18 to Mar. 16.....	7	181	87.90	47.44
Aug. 5 to Sept. 17.....	8 whites... 7 yolks... }	183	88.19	47.96
Oct. 5 to Nov. 2.....	4	54	87.99	47.54

It will be seen that in August and September, when the industry considers the quality of the eggs lowest, the maximum quantity of water is found in both white and yolk. In the early spring, when eggs are undoubtedly of highest quality, the water content is lowest, and in the cool days of autumn it occupies a medium position. The statement of the increased water content of summer eggs is not made authoritatively, but only as a promising line of investigation on this subject. It can be emphatically stated, however, that analytical differences in tenths of per cent may, in so specialized a tissue as an egg, carry with them marked variations in physiologic functions and chemical stability.

The fat of an egg is almost exclusively in the yolk. According to Pennington¹ the ether extract of the yolk varies from 33.33 to 31.44 per cent, the average for 236 eggs examined being 32.68 per cent.

"MARKET FRESH" EGGS.

The eggs from which the preceding information was obtained can not be accepted as either a standard or an index of the eggs supplied to the people for food, because modern conditions of living and sources of food supplies make it impossible to furnish the market with eggs of uniform quality and minimum age. It is necessary, therefore, as already stated, to study the common market grades of shell eggs accepted by the housewife and compare these with the

¹ Loc. cit.

absolutely fresh eggs, as well as with the eggs put up for bakers' use. Accordingly, ten open-market purchases were made of eggs as they went to the consumer, and analytical data and candling records obtained, using the same method as in the case of the fresh eggs. The results are given in Table 3.

TABLE 3.—*Eggs from grocery store.*

Sample No.	Date of collection.	Cost per dozen.	Sold for—	Ammoniacal nitrogen (Folin method), wet basis.	Size of sample.	Description of sample under candle.
589	1911. Aug. 25	\$. 25	"Strictly fresh eggs" carton packed.	<i>Per cent.</i> 0.0011	<i>Eggs.</i> 24	Fresh.
590	...do...	. 20	"Good eggs"	.0018	24	Seconds.
591	...do...	. 20	...do.....	.0014	24	Mixed firsts and seconds.
592	...do...	. 20	...do.....	.0014	24	4 shrunken eggs, 5 very stale eggs, 1 blood ring.
636	Sept. 5..	. 25	"Strictly fresh eggs" carton packed.	.0010	24	
637	...do...	. 20	"Good eggs"	.0014	24	5 seconds.
638	...do...	. 20	...do.....	.0022	24	22 stale eggs.
639	...do...	. 15	...do.....	.0021	12	9 stale eggs, 1 hatch-spot egg, 1 blood ring.
640	...do...	. 20	"Fresh eggs"	.0013	.....	5 slightly heated.
	1912. June 19	. 175	Dirty eggs	.0010	8	Fresh.

Bacterially these eggs did not differ from the strictly fresh eggs. According to the content of ammoniacal nitrogen they varied from absolutely fresh to the usual stale, but not rotten, eggs. The price usually, but not invariably, was in accord with the quality. The carton-packed eggs were individually marked with the sign of the producer, who had a reputation for quality to maintain.

RELATION BETWEEN BACTERIAL MULTIPLICATION AND CHEMICAL CHANGES.

Experiments have shown that evidences of bacterial decomposition can not be recognized by the sense of sight and smell until the organisms have increased enormously in the food substance.

There is an interesting problem involved in the study of the relation between bacterial multiplication and chemical evidences of the metabolic and catabolic changes that must accompany life processes. Bacteria to the number of millions per gram have been considered evidences of an altered chemical composition. Yet more recent observations would indicate that, for certain substances at least, the number of organisms must approach the 100 million per gram mark before the analytical methods for the detection of substances indicative of bacterial life can be applied satisfactorily. Such, for example, has been the finding of Hastings, Evans, and Hart,¹ who have studied

¹ Wisconsin Agricultural Experiment Station Research Bul. 25.

the relation between bacterial multiplication and the formation of lactic acid in milk; Burri and Kursteiner¹ state that the lactic-acid organisms of milk may increase to 100 millions per cubic centimeter before there is a definite rise in acidity. The same observation has been made by Pennington² and associates when investigating the decomposition of chicken flesh. In connection with this last study it was found that a marked rise in the ammoniacal nitrogen content of the flesh did not appear when the bacterial counts indicated a few million organisms per gram, but at the next examination, when the count was usually in the hundreds of millions, a rise was commonly found. The principles observed by the investigators cited are corroborated by the results of the study of bacterial content and chemical changes in eggs.

Not until chemical analyses show an increase in the ammoniacal nitrogen are the senses able to detect infected eggs readily. Studies discussed in detail in another section of this bulletin (p. 73) showed that sour eggs which in the early stages are, with difficulty, detected by the sense of smell, and eggs with light green albumen, which are recognized by careful scrutiny, contain bacteria in many millions.

Eighty commercial samples which contained organisms capable of producing gas from lactose in the presence of bile salt were examined for *B. coli*, as described in the chapter on laboratory practice (p. 76).

A portion from each of the higher dilution fermentation tubes, which showed gas, was plated on Endo's medium, or on lactose litmus agar, and from each plate having typical coli-like colonies several were selected for examination.

Organisms conforming strictly to the definition for *B. coli communis*, in the 1905 report of the American Public Health Association on Standard Methods of Water Analysis, were isolated from 55 per cent of the samples examined. Probably 15 per cent more contained organisms which would be classed as typical *B. coli* by a majority of observers because they differed very slightly from the definition just given. In the remaining 30 per cent of samples, which were not found to contain typical *B. coli*, the predominating gas-producing organism was *B. (Lactis) aerogenes*. Of the typical *B. coli* organisms examined 81 per cent produced gas from sucrose. Practically all of the organisms examined would be classed as members of the *Colon aerogenes* group. If gas production from various sugars is sufficient to distinguish between varieties of these organisms, a very large number of varieties were isolated. Some of them differed from any at present described in the literature.

¹Centralbl. Bakt., 1911, 2. abt., 30: 241.

²U. S. Dept. Agr., Bureau of Chemistry Cir. 70.

A detailed study of the organisms isolated is now in progress in this laboratory. A special report will be issued dealing with this phase of the work.

EXAMINATION OF EGGS OPENED ASEPTICALLY IN THE LABORATORY.

Because of the great diversity of conditions to which an egg in the shell may be subjected, the corresponding variety in the results which may follow, and because each individual egg must be considered as an individual by the candler and the egg breaker, even though its individuality is finally lost in the mixing, drying, or freezing of the commercial product, the study to be reported here had to deal first with single eggs of the various types found in commerce and which may or may not be used by the breaker in his output intended for food.

Tables 4 to 13 give the bacterial content of 300 individual eggs and 26 small samples, aggregating 981 eggs, classified in accordance with their most important or striking characteristic or the one probably responsible for the condition of the egg when it was examined. For example, an egg might show a heavy, settled yolk in a sound, clean shell, in which case it would be found in Table 5, under the heading of "Individual eggs with settled yolks." But if that egg, in addition to the settled yolk, had a dirty or cracked shell, it would be classed in Table 7 or Table 8, devoted to dirty-shell eggs and cracked-shell eggs, respectively.

The eggs were examined by means of a candle and their appearance described before the contents of the shell were studied bacteriologically. The classification of the eggs was made on these observed characteristics, and on others noticed when the shell was broken, rather than on the bacterial condition revealed by the laboratory work. The history of these eggs was known only in a very few instances. None of them were "market firsts," or high-class eggs, when they were received.

The study of the individual egg is logically followed by a study of a number of eggs which are similar when graded by means of the candle and by the characteristics observed on opening. Such samples of like eggs, aseptically opened, follow the report of the individual eggs in a number of the tables. The technique used is described on page 74. The samples were analyzed for the amount of loosely bound nitrogen they contained, as well as for the number of organisms.

STALE EGGS.

A very large proportion of the eggs going to the breakers are simply stale; that is, the shell shows an enlarged air space, the yolk has gained in opacity and definiteness of outline, and it is com-

monly either above or below the normal meridian position. (See Pl. II.) The white is frequently thin, and many times rough handling, combined with other age-accentuating conditions, have so separated the membrane lining the shell from the membrane inclosing the egg proper that the form and position of the air space can change as the egg is turned. This appearance has caused the trade term "weak eggs" or "watery eggs." But because these terms are loosely used and have several meanings in different sections of the country, or among different candlers, such conditions are characterized in this report as "movable air cells," this term actually describing the change which has occurred.

In the late summer and autumn, when the lay has fallen off and the country merchants are withholding stocks for coming high prices, such eggs form a very large proportion of the current receipts of the cities and are, of necessity, used by all of the community who depend upon such sources for their egg supply.

When warm weather prevails many of these stale eggs show what is termed "heat"; that is, the yolk rises in the shell and is flattened, the white becomes thinner than normal, and the air space increases in size. These changes, well shown in Plate II, take place in fertile and infertile eggs, both of which become distinctly stale if kept sufficiently long. In the fertile egg, however, there comes a second series of changes, namely, incubation, which, in the very earliest stages after the egg is laid, can not be distinguished by the candling method, but has as one of its accompaniments the rising of the yolk to the upper part of the shell. When the shell of a "heated" egg is broken the germinal spot, if fertile, is seen to be slightly thickened. In an infertile egg the germinal spot is seen with difficulty. Such eggs, whether fertile or infertile, are good in appearance, odor, and taste, but deterioration is rapid and they will not stand long hauls to market nor keep well in cold storage. Hence, such eggs are used in the egg-breaking plants. Their bacterial content is shown in Table 4, where it will be seen that the bacteria are either very few or entirely absent, and that, bacterially, at least, these eggs are not to be distinguished from eggs just laid.

TABLE 4.—*Stale eggs.*¹

INDIVIDUAL EGGS.

Sample No.	Date of examination.	White.		Yolk.		Number of gas-producing bacteria per gram in lactose bile.		Description.	
		Total number of bacteria per gram on plain agar.							
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	White.	Yolk.		
3023-1	1911. Mar. 28	0	0	0	0			Slightly dirty shell. Clean shell. Clean-shelled guinea egg kept in cold storage 1 year and in candling room 1 week. Clean shell, slightly shrunken, small hatch spot and floating yolk. Clean shell; slight shrinkage. Weak white and yolk, hatch spot not enlarged, movable air cell. Clean-shelled, fresh infertile egg, kept at room temperature for 8 days. Weak white and yolk, marked shrinkage, slightly movable air cell. Clean-shelled, infertile egg, kept at room temperature for 8 days. Watery white, marked shrinkage, slightly movable air cell.	
3023-2	...do....	0	0	0	0				
3023-4	...do....	5	0	5	0				
3024-7	Apr. 4	0	5	10	0				
3026-1	Apr. 7	10	0		0				
3026-7	...do....	20	0	10	0				
4005	June 12	0	20	0	0	0	0		
4039	July 8	0	0	0	0	0	0		
4040	...do....	0	0	0	0	0	0		

¹ Samples 3001 to 3031, inclusive, were examined by Christine S. Avery.

SMALL COMPOSITE SAMPLES.

Sample No.	Source. ¹	Date of examination.	Total number of bacteria per gram on plain agar.		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen (Folin method).		Per cent of moisture.	Description.
			Incubated at 20° C.	Incubated at 37° C.		Wet basis.	Dry basis.		
4579	D 3	1912. June 19	0	0	0	0.0017	0.0061	72.13	63 eggs; small, most of them shrunken.
4630	E 4	June 28	50	200	0	.0018	.0064	72.02	66 eggs; shrunken.
296	B	1911. July 19	600	2,400	0	.0016	.0069		8 eggs; shrunken.

¹See p. 40.

Even when 5 dozen or more such eggs are mixed together the bacterial findings for the individual of the type hold good. The loosely bound nitrogen in these samples of "stale" eggs is the same as, or a little less than, that found in the "grocery" eggs purchased in the open market during the summer of 1911.

EGGS HAVING SETTLED YOLKS.

Table 5 shows another type of deterioration, which is further advanced and more specific than that meant by the general term "stale." The yolk has become more opaque and consequently clearer in outline when viewed by the aid of the candle and has fallen to the pointed end of the shell (see Pl. III), where it turns sluggishly when rotated. Very frequently when these eggs are opened the yolk is seen to have a very thin, weak membrane. During warm weather, when incubation goes on almost continuously, though very slowly, these eggs with settled yolks frequently show a germinal area about one-fourth inch in diameter, having a visible white line through their center—the "primitive streak" of the embryologists. (See Pl. II.) Their odor is generally good and their taste not objectionable, except for soft boiling or poaching.

TABLE 5.—*Individual eggs with settled yolks.*

Sample No.	Date of examination.	White.		Yolk.		Whole egg.	Number of gas-producing bacteria per gram in lactose bile.		Description.
		Total number of bacteria per gram on plain agar.					White.	Yolk.	
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 37° C.			
4004	1911. June 12	70	0				0		Watery white. Enlarged hatch spot; bloated yolk.
4013	June 13	0	0	30	0		0	0	
4014	..do....	0	0	20	0		0	0	Enlarged hatch spot. Enlarged hatch spot; bloated yolk.
4015	..do....	30	0	20	10		0	0	
4016	..do....	20	0	40	0		0	0	
4018	..do....	0	0	30	10		0	0	
41089-7	1912, Aug. 31					64,000			Marked shrinkage. Very weak yolk which broke when egg was opened.
41089-8	..do....					10 at 100			
41089-12	..do....					54,000			Marked shrinkage. Marked shrinkage; yolk broke when egg was opened.
41089-18	..do....					240,000			
41089-19	..do....					0 at 100			Marked shrinkage. Decidedly weak yolk which broke when egg was opened.
41089-21	..do....					0 at 100			
41089-27	..do....					0 at 100			Marked shrinkage. Do. Do.
41089-28	..do....					0 at 100			
41089-33	..do....					0 at 100			Marked shrinkage; yolk broke when egg was opened.
41089-38	..do....					0 at 100			
41089-39	..do....					0 at 100			Marked shrinkage. Do. Do.
41089-41	..do....					0 at 100			
41089-42	..do....					0 at 100			Marked shrinkage; yolk broke when egg was opened.
41089-44	..do....					0 at 100			
41089-45	..do....					0 at 100			Marked shrinkage. Do. Do.
41089-46	..do....					0 at 100			
41089-50	..do....					0 at 100			Marked shrinkage. Do. Do.
41089-53	..do....					0 at 100			
41089-55	..do....					0 at 100			Do. Do.
41089-57	..do....					0 at 100			
41089-58	..do....					0 at 100			Do. Do.
41089-59	..do....					0 at 100			
41089-61	..do....					0 at 100			Yolk broke when egg -was opened. Marked shrinkage.
41089-62	..do....					0 at 100			
41089-63	..do....					0 at 100			

10 at the dilution given indicates that no organisms were observed on the plate.

The bacterial content of these eggs is generally slightly higher than in the earlier stage of staleness unless aging has occurred at the low temperatures of the egg storage warehouse, when the count is as low as or lower ¹ than in new-laid eggs.

This type of deteriorated egg is very common in the breakers' stocks, and, indeed, throughout the market seconds in both summer and winter, due to rapid deterioration from high temperatures in the one case and to the slow deterioration which occurs at 29° to 31° F. in the other. The market life of such eggs is shorter than when deterioration is not so far advanced. Hence the egg shipper with a breaking establishment at hand prefers to break and freeze or dry these eggs while they are still edible rather than to risk the certain losses of a haul to the consumer.

EGGS CHANGED BY INCUBATION.

Table 6 shows typical bacterial findings in eggs where deterioration had progressed along different lines than those described under stale eggs and eggs with settled yolks. In the first group of 20 eggs the development of the chick had not reached the blood-forming stage, which normally occurs in about 24 hours when the temperature is that of the hen, 103° F., but which had gone sufficiently far for the candler to observe a small darkened area on the yolk. This in the industry is known as a "light spot," and when the egg is broken it is usually seen as a round area about three-eighths inch in diameter, having two distinct zones, an inner and outer circle (see Pl. II). Such eggs, constantly sold in their shells for food purposes, are used by the housewife without question if the odor is good and if the white and yolk are intact. They do not ship well because the yolk membrane is often weak, and many kinds of spoilage may develop in them on short notice. Hence they are sent in large numbers to the egg breakers in the producing regions.

¹ Unpublished results on storage eggs.

TABLE 6.—*Eggs changed by incubation.*

INDIVIDUAL EGGS SHOWING HATCH SPOT.

Sample No.	Date of examination.	White.		Yolk.		Whole egg.		Number of gas-producing bacteria per gram in lactose bile.			Description of sample.
		Total number of bacteria per gram on plain agar.						White.	Yolk.	Whole egg.	
		Incu- bated at 20° C.	Incu- bated at 37° C.	Incu- bated at 20° C.	Incu- bated at 37° C.	Incu- bated at 20° C.	Incu- bated at 37° C.				
3006-1	1910. Jan. 20					0	41				
3008-1	Jan. 23					39	13				
3008-3	do.					38	230				
3009-3	Jan. 27	7	0								
3009-4	do.	11	11								
3024-1	1911. Apr. 4	4	75								
4006	June 12	0	20	0		0	0		0	0	
4038	July 8					0			0	0	
4057	July 13	0	0	260	30				0	0	Small hatch spot; slightly dirty shell; some shrinkage.
397	July 31					10	10			0	
398	do.					85	10			0	
399	do.					20	5			0	
400	do.					75	20			0	
401	do.					20	15			0	
4061	Sept. 5	590	340	90					0	0	
4065	do.	90	0	30	0				0	0	
4076	Sept. 14	30	0	25	150				0	0	
4077	do.	30	40	0	0				0	0	
4078	do.	0	0	0	0				0	0	
4079	do.	0	0	0	0				0	0	

Fixed air cell.

Very movable air cell.

Good odor; watery white; marked shrinkage; movable air cell.

Small hatch spot; slightly dirty shell; some shrinkage.

Hatch spot size of dime; good odor on opening; firm white; marked shrinkage; broken air cell.

Very large hatch spot; good odor upon opening; fairly clean; marked shrinkage; broken air cell.

Hatch spot size of dime; good odor on opening; weak white and yolk; clean shell; marked shrinkage; broken air cell.

Large hatch spot; good odor on opening; weak white and yolk; clean shell; marked shrinkage; broken air cell.

Hatch spot size of nickel; good odor on opening; weak white and yolk; clean shell; marked shrinkage; broken air cell.

Hatch spot size of nickel; good odor on opening; weak white and yolk; clean shell; marked shrinkage; broken air cell.

Hatch spot size of nickel; good odor on opening; weak white and yolk; clean shell; marked shrinkage; broken air cell.

Hatch spot size of nickel; good odor on opening; weak white and yolk; clean shell; marked shrinkage; broken air cell.

TABLE 6.—*Eggs changed by incubation*—Continued.
INDIVIDUAL EGGS WITH DEAD EMBRYOS (INCUBATION 48 HOURS OR MORE).

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar.					Number of gas-producing bacteria per gram in lactose bile.			Description of sample.
		White.		Yolk.		Whole egg.				
		Incu- bated at 20° C.	Incu- bated at 37° C.	Incu- bated at 20° C.	Incu- bated at 37° C.	Incu- bated at 20° C.	Incu- bated at 37° C.	White.	Yolk.	Whole egg.
4058	1911. July 13	20	0	35	0					0
4101	Nov. 1					0	130			0
4102	do					85	49,000			0
4109	Nov. 7					18,000,000	28,000,000			0
4111	do					100,000	150,000			0
4112	do					3,400	4,600			1,000
4113	do					120	150			0
4115	do					150	300			0

Contained an embryo about 8 days old; bad odor on opening; weak white and broken yolk; moderately clean shell; marked shrinkage; movable air cell.
 Contained a broken-down blood ring; odor not bad on opening; white and yolk mixed; clean shell; marked shrinkage; movable air cell.
 Contained much blood and an embryo about 5 days old; white and yolk mixed; clean shell; marked shrinkage; movable air cell.
 Contained a broken-down blood ring; shell smeared and stained with feathers and feces; very stale odor on opening; white and yolk mixed; fixed air cell.
 Contained a large chick; contents black under candle; shell not fresh looking; ethereal odor.
 Contained an embryo about 2 days old; odor not bad on opening; white and yolk mixed; fairly clean shell; marked shrinkage; movable air cell.
 Contained much blood and an embryo about 2 days old; stale odor; fairly clean shell; white and yolk mixed; marked shrinkage; movable air cell.
 Contained an embryo about 5 days old; stale odor on opening; fairly clean shell; marked shrinkage; movable air cell.

Bacterially, these eggs show a wider range and a slightly higher average count than the two types previously discussed. All had the yolk and the white intact. In 11 of the examinations reported the white and yolk were studied separately. Two of the series were sterile and not one showed the presence of *B. coli*. The fact that the odor on opening these eggs was universally good is to be emphasized.

The second series of Table 6 is composed of eggs which show before the candle the presence of blood in the germinal disk, and which are therefore equivalent to eggs at least 48 hours old at 103° F. In all of the eggs in this series the embryo was either alive or very recently dead, and the odor of the egg when opened was good. In all of them the presence of blood could be distinguished by means of the candle (see Pl. V). These eggs, in most instances, could be separated into white and yolk. The average count for such eggs showing blood rings, but without disintegration in the structure of the egg itself, is low, and some eggs are sterile.

The third series, where incubation had continued for more than the equivalent of 48 hours at 103° F. and where the embryo was dead and the structure of the egg damaged to a greater or less extent, shows a universally higher count than the other series and some individual counts which are strikingly high. *B. coli* were noted but once in this series. It will be observed that only one egg was separable into white and yolk. The odor was sometimes good and sometimes stale.

EGGS HAVING DIRTY SHELLS.

The egg with a dirty shell is one of the most objectionable factors of the egg industry. The contents may be fresh and the egg itself may be large, but the dirt on the shell consigns it at once to the seconds, and it brings a lowered price all through the market. Dirty-shell eggs do not store well and are therefore not available for holding when the surplus production is greatest and when the market can secure more good, clean eggs than it needs. Often they scarcely pay the expense of marketing. The breaker, therefore, removes the dirty shell and endeavors to put the contents into a form in which it can be marketed. The very objectionable filth on the exterior of the shell naturally inclines one to the opinion that the contents of the egg may also be contaminated. Such outer filth is not conclusive evidence that the contents are infected.

Table 7 gives the bacterial findings for 51 dirty-shell eggs of various grades of seconds and worse and 9 small samples, aggregating 1,164 eggs. Winter, spring, and summer eggs are included. The dirt on the shell consisted mostly of chicken feces and some dried mud or dried egg. Some of the shells were stained. These stains, which can not ordinarily be washed off, generally indicate that water as well as filth has come in contact with the egg shell.

TABLE 7.—*Eggs having dirty shells.*

INDIVIDUAL EGGS.

Sample No.	Date of examination.	White.		Yolk.		Number of gas-producing bacteria per gram on lactose bile.		Description of sample.
		Total number of bacteria per gram on plain agar.						
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	White.	Yolk.	
3019-1	1911, Mar. 14	60	20					Good quality.
3019-2	do.....	25	70					Do.
3019-3	do.....	75	5					Do.
3019-4	do.....	25	0					Do.
3020-1	Mar. 20	0	0					State under candle; enlarged hatch spot.
3020-3	do.....	0	0					Do.
3020-5	do.....	0	0					Do.
3020-7	do.....	0	0					Do.
3021-4	Mar. 21	0	0					Do.
3024-3	Apr. 4	0	0					Green stained shell, looks as though it had been washed; marked shrinkage.
3024-5	do.....	0	5					Very dirty shell.
3025	Apr. 6	0	0					Badly stained egg with a tough vitelline membrane.
3026-2	Apr. 7	15	0					Very dirty shell; watery white; enlarged hatch spot; slight shrinkage.
562	Aug. 21	70	70					A large hatch spot; slight shrinkage.
4067	Sept. 5	24,000,000	5,400,000	12,000,000	7,800,000	0	0	Peculiar odor when egg was opened.
4080	Sept. 21	190	20	0	0	0	0	Very dirty shell; bad odor on opening; weak white; enlarged hatch spot; some shrinkage; fixed air cell.
4081	do.....	0	0	0	0	0	0	Fecal dirty shell; good odor on opening; weak white; hatch spot size of dime; some shrinkage; fixed air cell.
4082	do.....	0	0	0	0	0	0	Fecal dirty shell; slightly stale odor on opening; weak yolk; small hatch spot; some shrinkage; fixed air cell.
4083	do.....	3,100,000	2,200,000	1,600,000	1,400,000	0	0	Good odor when egg was opened; weak white; some shrinkage; broken air cell.
4084	do.....	0	0	35	125	0	0	Stained shell; looked as though it had been washed; stale odor when egg was opened; weak white and yolk; small hatch spot; marked shrinkage; very movable air cell.
4086	Oct. 9	10	550	10		0	0	Fecal dirty shell; stale odor; weak white and yolk; hatch spot size of dime; some shrinkage; slightly movable air cell.
4096	Oct. 31	15	190	200	120			Fecal dirty shell; good odor when egg was opened; very much enlarged hatch spot; some shrinkage; movable air cell.
4097	do.....	0	0	0	0	0	0	Shell looks as though it had been stained by damp straw; weak white; slightly enlarged hatch spot; some shrinkage; movable air cell.
4098	do.....	50	70	0	0	0	0	Fecal dirty shell; weak white and yolk; enlarged hatch spot; some shrinkage; movable air cell.

4099	...do....	5	15	15	35	0	0	Shell smeared with broken egg; weak white; sun-spotted yolk; hatch spot not enlarged; some shrinkage; movable air cell.
4100	...do....	270	260	550	650	0	0	Shell looks as though stained by dirty feet; also smeared with broken egg; firm white; yolk at top of egg; some shrinkage; fixed air cell.
4116	Nov. 7	2,900	1,700	1,000	1,100	0	0	Very badly brown-stained shell; stale odor when egg was opened; some shrinkage; fixed air cell.
4124	Nov. 14	30	45	30	30	0	0	Somewhat stained and smeared with feces; good odor when egg was opened; weak white; hatch spot not enlarged; movable air cell.
4125	...do....	30	15	25	35	0	0	Shell considerably smeared with feces; good odor when egg was opened; weak white; hatch spot not enlarged; movable air cell.
4126	...do....	30	0	10	25	0	0	Shell smeared with ground dirt, but not stained; hatch spot not enlarged; good odor when egg was opened; marked shrinkage; fixed air cell.
4128	...do....	72,000	4,000	.....	.....	0	0	A very badly brown-stained shell; good odor; hatch spot not enlarged; some shrinkage; fixed air cell.
4129	...do....	1,600	25	65	45	0	0	Shell smeared with feces; odor not exactly good when egg was opened; firm white; hatch spot not enlarged; slight shrinkage; fixed air cell.
4130	...do....	45	10	60	50	0	0	Shell smeared with dirt and feces; good odor on opening; some shrinkage; movable air cell.
4131	Nov. 23	5	10	25	0	0	0	Shell smeared with feces; weak yolk; hatch spot not enlarged; some shrinkage; movable air cell.
4133	...do....	0	10	5	20	0	0	Shell greasy and smeared with feces; good odor when egg was opened; hatch spot not enlarged; marked shrinkage; movable air cell.
4134	...do....	0	0	0	0	0	0	Shell stained and smeared in spots with feces; good odor when egg was opened; heavy roller; hatch spot size of dime; one-third shrinkage; movable air cell.
4135	...do....	0	10	40	20	0	0	Shell smeared with feces; good odor when egg was opened; slightly enlarged hatch spot; some shrinkage; fixed air cell.
4136	...do....	0	0	60	100	0	0	Shell smeared in spots with feces; weak white; weak yolk; hatch spot not enlarged; heavy roller; marked shrinkage; movable air cell.
4137	Nov. 13	30	4,600	290	75	0	0	Stained shell; firm white; hatch spot not enlarged; fixed air cell.
4138	Dec. 14	120	45	.....	220	0	0	Shell looked as though it had been wet; considerable shrinkage.
4139	...do....	1,800	0	2,100	0	0	0	Shell smeared with feces; weak white; hatch spot not enlarged; some shrinkage; movable air cell.
4140	...do....	0	0	130	0	0	0	Green-stained areas on shell; good odor when egg was opened; hatch spot not enlarged; little shrinkage; fixed air cell.
4142	...do....	30	0	1,900	15	0	0	Fecal dirty shell; good odor when egg was opened; firm white; hatch spot not enlarged; quick roller; considerable shrinkage.
4143	...do....	0	0	.....	0	0	0	Fecal dirty shell; barn odor when egg was opened; very weak white and yolk; considerable shrinkage; movable air cell.
4147	Dec. 15	45	100	180	75	0	0	Weak white; heavy quick roller; some shrinkage; movable air cell.
4148	...do....	400	220	1,200	640	0	0	Shell smeared with broken egg and other dirt; hatch spot not enlarged; considerable shrinkage; movable air cell.
4149	...do....	95	30	680	140	0	0	Fecal dirty shell; good odor when egg was broken; some shrinkage; movable air cell.
4150	Dec. 16	0	0	0	0	0	0	Fecal dirty shell; cracked on bottom; weak egg; heavy roller; enlarged hatch spot; some shrinkage; movable air cell.
4152	...do....	0	0	15	5	0	0	Shell smeared with egg from case; good odor when egg was opened; hatch spot not enlarged; considerable shrinkage; movable air cell.
4154	...do....	0	0	0	.....	0	0	Very weak egg; heavy roller; movable air cell.

¹ Samples 4124 to 4154 were selected Nov. 14, 1911. The eggs with odd numbers were washed and those with even numbers were not. All were kept in the laboratory at ordinary temperatures and different lots plated at varying intervals of time.

TABLE 7.—*Eggs having dirty shells*—Continued.

SMALL COMPOSITE SAMPLES.

Sample No.	Source.	Whole egg.		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Moisture.	Size of sample.	Condition of sample.	
		Date of examination.	Total number of bacteria per gram on plain agar.		Wet basis.	Dry basis.				
Incubated at 20° C.	Incubated at 37° C.	0.0015	0.0082	Per cent.	Eggs.					
265		1911.		90	0	0.0015	0.0082		6	Good quality; very dirty. Do. Do. Do.
278	.....	July 17	.....	5	0	.0017	.0073	.....	6	
552	.....	do.	.....	32,500	.....	.0018	.0070	.....	38	
553	.....	Aug. 21	.....	0 in 100	.....	.0013	.0068	.....	38	
554	.....	do.	.....	0 in 100	.....	.0017	.0070	.....	38	
555	.....	do.	.....	0 in 100	.....	.0017	.0061	.....	38	
4582	D 3	1912.		0 in 100	0	.0017	.0061	72.02	864	Very stale and dirty.
4631	E 4	June 19	.....	5,100,000	0	.0024	.0083	71.02	64	
4951	E 5	Aug. 9	.....	600,000	100	.0022	.0078	71.83	72	

The contents of these dirty-shell eggs listed in Table 7 are varied. Some show definite signs of incubation; some are aged eggs, as shown by shrinkage; some show weak whites, some settled yolks, etc. Bacterially this series, as might be expected, is very divergent in the number of organisms observed. Two eggs out of the 51 contain millions of organisms per gram in both white and yolk; 4 show a count running into the thousands; 9 have more than a hundred organisms per gram; and of the 36 remaining, 15, or 41.6 per cent, are sterile. It is of great interest to observe that although so many of these dirty shells were smeared with feces, which undoubtedly contained *B. coli*, this organism was not once obtained in the body of the egg, either in the white or in the yolk, and that it did not appear in those eggs which had been wet is a still more striking fact. This observation is in accordance with the work of Maurer.¹

Sample 4083, with 3,100,000 organisms in the white, had a stale odor on opening and a stained shell, which looked as though it had been wet.

Sample 4128 had a very badly brown-stained shell, and though the odor of the egg was good on opening, 72,000 organisms per gram were found in the white. Sample 4137 showed 4,600 organisms per gram in the white, which may, perhaps, be accounted for by the stained shell. On the whole it is the stained shell which seems most likely to be the offender, an opinion which is strengthened by the observation that where there is a count of any magnitude it is not only most commonly in the eggs having stained shells, but the organisms are usually more abundant in the white of the egg than in the yolk, from which one might infer that the infection is from the exterior.

The nine samples, composed of more than one dirty-shell egg, vary in bacterial content just as do the individual eggs. The chemical analysis shows that the loosely bound nitrogen varies with the character of the egg, not with the quantity of dirt on the shells. Sample 4631, for instance, shows 0.0024 per cent of nitrogen and is described as very stale, but it was not any dirtier than Sample 553, wherein only 0.0013 per cent of nitrogen was obtained.

If one may draw any conclusion from the findings set forth in Table 7 it must be that the dirty shell, per se, is not a sufficient ground on which to condemn an egg, though the odor of the egg when opened should be carefully observed, especially if the shell shows stains or other evidences of having been wet.

¹ Bacteriological Studies on Eggs. Kansas State Agricultural College Bul. 180, 1911.

EGGS HAVING CRACKED SHELLS.

Mechanical injury to eggs, due to rough handling, is another great money loss to the egg industry and a food loss to the consumers. Many eggs are completely wrecked and are termed "mashed" eggs by the industry. In this case they are not only lost but they soil a number of eggs otherwise good. Where the shell is so broken that the contents are escaping the egg is termed a "leaker." In addition to leakers the industry has to contend with enormous numbers of "checks"—that is, eggs which have cracked shells but intact membranes.

Leakers are thrown out at every stage of handling, from the country merchant or egg peddler to the city retailer, and are generally a total loss. Checks are disposed of if possible and as near the gathering point as may be, because they are weakened mechanically and are free food for any bacterium or mold that may chance to fall into the crack. Hence they are sure, in commerce, to rot quickly. The cracked eggs coming to the breaker in the producing section are received by him much sooner after the damage is done than by the breaker in the consuming center, and for that reason they are usually in better bacterial condition. Table 8 gives the results of the examination of 56 of these cracked eggs, both blind and visible checks. Some of these eggs were fresh and above reproach except for the damaged shell; others had dirty as well as cracked shells, hatch spots, weak yolks, thin whites, etc.

TABLE 8.—Eggs with cracked shells (*membranes intact*).

INDIVIDUAL EGGS.

Sample No.	Date of examination.	White.		Yolk.		Whole egg.		Number of gas-producing bacteria per gram in lactose bile.			Description of sample.
		Total number of bacteria per gram on plain agar.						White.	Yolk.	Whole egg.	
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.				
179-1	1911.							25		0	Firm yolk.
179-2	July 6					15	230	0		0	Do.
208	July 8					370,000	10,000+	0		10,000+	Cracks visible before candle only; bad odor.
209	do.					0	0	0		0	Many cracks on top of egg; visible before candle only.
210	do.					15	25	0		0	Cracks visible before candle only.
211	do.					260	35	0		0	Hole in top of egg; membrane intact.
218	July 11					65	0	0		0	Cracks visible before candle only; firm yolk.
219	do.					25	5	0		0	Heavy blood ring; cracks visible before candle only.
220	do.					65	20	0		0	Visible cracks; hole in one end; weak yolk.
221	do.					55	10	0		0	Visible cracks.
222	do.					40	10	0		0	Open cracks; firm yolk.
223	do.					30	25	0		0	Small crack; cracks visible before candle only; weak yolk; small hatch spot.
224	do.					10	5	0		0	Visible cracks; cracks visible before candle only; enlarged hatch spot; firm yolk.
225	do.					25	0	0		0	Cracks visible before candle only; weak yolk; small hatch spot.
226	July 25					5	15	0		0	Good quality.
331	do.					40	40	0		0	Do.
332	do.					20	30	0		0	Do.
333	do.					10	5	0		0	Do.
334	do.					0	10	0		0	Do.
336	do.					5	10	0		0	Do.
337	do.					5	20	0		0	Do.
338	do.					10	5	0		0	Do.
339	do.					20	20	0		0	Do.
341	do.					240	290	0		0	Crack with a hole; good quality.
342	do.					10	15	0		0	Do.
343	do.					5	5	0		0	Do.
344	do.					20	5	0		0	Do.
451	Aug. 15					150	125	0		0	Visible cracks; excelsior and paper filler was present on shell and also in egg, having entered same through crack.

TABLE 8.—*Eggs with cracked shells (membranes intact)*—Continued.

INDIVIDUAL EGGS—Continued.

Sample No.	Date of examination.	White.		Yolk.		Whole egg.				Number of gas-producing bacteria per gram in lactose bile.			Description of sample.
		Total number of bacteria per gram on plain agar.						White.	Yolk.	Whole egg.			
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.						
3019-5	1911. Mar. 13	32	0										Clean shell.
3019-6	do.	43	0	200	75								Do.
3019-8	do.	0	0										Very dirty shell; watery white.
4010	June 12			0	0							0	Visible cracks; firm white; no hatch spot; fixed air cell.
4051	July 19	0	0	0	0						0	0	Visible cracks; clean shell, yolk stuck near bottom; hatch spot; good odor; movable air cell; marked shrinkage.
4062	Sept. 5	370,000	370,000	2,200,000	Imnumerable in 10,000.					100+	100+		Visible cracks; dirty shell; watery white; hatch spot; stale odor; marked shrinkage; movable air cell.
4064	do.	150	75	160	100					0	0		Visible cracks; somewhat dirty shell; hatch spot; good odor; marked shrinkage; movable air cell.
4066	do.		110	30	20					0	0		Visible cracks; clean shell; hatch spot size of a dime; good odor; fixed air cell.
4068	do.	Imnumerable in 1 to 100.	120,000	Imnumerable in 1 to 100.	Imnumerable in 1 to 100.					0	0		Visible cracks; dirty shell; hatch spot size of a dime; watery white; good odor; movable air cell.
4071	Sept. 8	15	70		75					0	0		Visible cracks; clean shell; hatch spot size of a quarter; weak white; marked shrinkage; movable air cell.
4072	do.	40	25	25	35								Visible cracks; clean shell; hatch spot size of a 5-cent piece; good odor; some shrinkage; fixed air cell.
4073	do.	170,000,000	33,000,000	49,000,000	9,100,000					100,000+	100,000+		Visible cracks; dirty shell; bad odor; hatch spot size of a nickel; weak white; some shrinkage; fixed air cell.
4074	do.	20	35	530	370					0	0		Visible cracks; clean shell; hatch spot size of 1 square cm; watery white; good odor; some shrinkage; fixed air cell.
4080	Oct. 10	0	0	25	0					0	0		Visible cracks; clean shell; hatch spot size of a dollar; weak white; marked shrinkage; fixed air cell.
4091	do.	0	2,700	20	950								Visible cracks; clean shell; stale odor; broken air cell.
4092	do.	0	20		35					0	0		Visible cracks; clean shell; stale odor; weak white; no hatch spot; very marked shrinkage; movable air cell.

4093	...do....	0	0	0	0	0	0	0	Visible cracks; moderately clean shell; stale odor; weak white; hatch spot size of a dime; marked shrinkage; movable air cell.
4094	...do....	0	10	10	3	0	0	0	Visible cracks; clean shell; stale odor; marked shrinkage; movable air cell.
4095	...do....	0	0	0	7	0	0	0	Visible cracks; dirty shell; stale odor; weak white; hatch spot size of dime; some shrinkage; movable air cell.
4107	Nov. 1	20	10	5	20	0	0	0	Visible cracks on top of egg; shell dirty in places; good odor; watery white; no hatch spot; marked shrinkage; movable air cell.
4117	Nov. 10	25	15	45	75	0	0	0	Visible cracks; fairly clean shell; good odor; small hatch spot; some shrinkage; fixed air cell.
4118	...do....	25	25	75	90	0	0	0	Visible cracks; clean shell; fresh odor; no hatch spot; marked shrinkage; fixed air cell.
4119	...do....	0	15	20	55	0	0	0	Visible cracks; clean shell; fresh odor; no hatch spot; fixed air cell.
4120	...do....	20	30	15	50	0	0	0	Visible cracks; shell dirty in spots; fresh odor; no hatch spot; some shrinkage; fixed air cell.
4121	...do....	15	45	35	15	0	0	0	Visible cracks; clean shell; fresh odor; a hatch spot; fixed air cell.
4122	...do....	30	45	50	30	0	0	0	Visible cracks; clean shell; fresh odor; weak white and yolk; marked shrinkage; movable air cell.
4123	...do....	10	25	15	5	0	0	0	Visible cracks; clean shell; fresh odor; weak yolk; fixed air cell.
4150	Dec. 16	0	0	0	0	0	0	0	Visible cracks on bottom of egg; fecal dirt on shell; no hatch spot; some shrinkage; movable air cell.

TABLE 8.—*Eggs with cracked shells (membranes intact)*—Continued.

SMALL COMPOSITE SAMPLES.

Sample No.	Source.	Date of examination.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folsom method.		Moisture.	Size of sample.	Description.
			20° C.	37° C.		Wet basis.	Dry basis.			
620	.....	1911, Aug. 30	450	150	0 in 100	0.0014	.....	Percent.	Eggs. 36	Current receipts.
621	.....	.....	150	300	0 in 100	.0014	.....	.....	36	Do.
622	.....	.....	650	50	0 in 100	.0015	.....	.....	36	Do.
623	.....	.....	0	200	0 in 100	.0015	.....	.....	36	Do.
4573	D3	1912, June 19	200	350	0	.0018	0.0065	72.09	72	Badly shrunken.
4632	E4	.....	97,000	15,500	10,000	.0019	.0067	71.58	72	Shrunken.
41043	D6	Aug. 23	5,300,000	2,500,000	10	.0024	.0083	71.24	72	14 hatch spots; 29 broken yolks.
41044	D6	.....	3,800,000	2,200,000	0	.0020	.0072	72.38	72	36 hatch spots.

Like the eggs with dirty shells, there is a wide variation in the number of bacteria, though only 5 out of the 56 individual eggs listed are sterile in a dilution of 1 to 10, and when the count is beyond a few hundred organisms per gram it is generally very high—that is, in the hundreds of thousands or millions. Four eggs have a bacterial content which is much higher than that observed in the other 52 eggs, ranging from 2,700 to 370,000,000 per gram. In three cases out of the four an objectionable odor was noticed when the egg was opened, and three of these eggs had dirty as well as cracked shells. *B. coli*, though sought in all but five of the samples, were found in but three instances and then in eggs which showed a high count. Here, again, the whites of the heavily infected eggs show a much higher count than the corresponding yolks. This is quite in line with the origin of the infection.

The samples from small lots of eggs with cracked shells bear out the findings from the individual eggs. Where the eggs with cracked shells are of good quality, both chemical and bacterial analyses indicate that fact. Where deterioration has begun, the cracking of the shell does not materially alter its course, but it hastens decay. Of course, the protection which the shell affords is lessened by cracking, and bacterial invasion is only a question of time and environment.

EGGS HAVING THE YOLK SEEPING INTO THE WHITE.

During warm weather, when the deterioration of eggs proceeds with great rapidity and in the most diversified fashion, many eggs are received at the concentrating centers, especially those reached by railroad or where the wagon haul is over rough roads, which show on candling filaments of yolk that have apparently found their way through apertures in the vitelline membrane for longer or shorter distances into the white.

Sometimes these filaments are very few and distinct, half an inch or more in length; in that case the egg white is usually normal in color, even between the filaments. Sometimes the seepage of the yolk into the white might be better described as diffuse, in which case very numerous and tiny filaments make a yellow zone around the yolk membrane, the outer portions of white remaining clear and the usual color. As the process of mixing progresses the white becomes more and more yellow and the vitelline membrane less and less resistant, until finally the latter ruptures and a complete mixing of yolk and white follows.

Even the most careful cracking of the shell at its equator is at times sufficient to rupture the yolk membrane extensively, thus permitting the yolk to escape entirely. At other times a fairly clean separation of white and yolk can be made. Generally such eggs exhibit, in addition to the filamentous yolk, distinct signs of age, such as shrinkage, and of rough handling, as shown by the movable air cell. Ordinarily the odor is good or somewhat stale, the sort of odor

that the housewife terms "eggy" or "strong." If the odor is not bad and if the mixing of the yolk and white is slight, the housewife uses these eggs for general cookery, though when the whites are to be whipped separately to lightness they are not satisfactory. The egg shipper does not attempt to send such eggs on long or hard journeys, because this mixing is accelerated by jarring; nor does he attempt to store them, because white and yolk continue to mix more and more rapidly. These eggs are therefore used very largely by the breakers. They should be examined very carefully for odor and appearance when broken, as they may be incipient forms of the "sour egg" (see p. 61). Table 9 illustrates the condition of this series.

TABLE 9.—*Eggs with the yolk seeping into the white.*
INDIVIDUAL EGGS.

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Description.
		20° C.	37° C.		
3006-4	1910. Dec. 12	77,000	83,000	-----	
3006-5	...do....	39	100	-----	
3010-2	...do....	25	15	-----	
4003	1911. June 12	10	10	0	
111-2	June 21	5	15	0	Marked shrinkage—fixed air cell.
111-3	...do....	60	0	0	
111-4	...do....	5	0	0	
111-5	...do....	30	0	0	
111-6	...do....	10	0	0	
111-7	...do....	0	0	0	
122	June 24	10	0	0	Early stage.
124	...do....	5	5	0	Do.
125	...do....	5	0	0	"Strong" odor.
136	1912. June 27	50	30	0	Early stage.
217	1911. July 11	10	10	0	
4103	Nov. 1	5	90	0	Clean shell; stale odor; marked shrinkage; movable air cell.
4108	Nov. 7	2,000,000	1,700,000	0	Shell clean, but not fresh looking; stale odor; marked shrinkage; movable air cell.

SMALL SAMPLES.

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Per cent of moisture.	Ether extract.	Size of sample.	
		20° C.	37° C.			Wet basis.	Dry basis.			Bacteriological.	Chemical.
115	1911. June 23	3	3	0	0			72.35	10.96	Eggs. 12	Eggs. 24
170	July 3	100	5	0	0	0.0033	0.0111	70.31	12.45	12	24
171	...do....	90	0	0	0	.0033	.0112	70.66	11.97	1	4
172	...do....	100				.0032	.0114	71.84	10.86	1	4
173	...do....	100	35	0	0	.0029	.0103	71.78	10.55	1	4
174	...do....	180	5	0	0	.0038	.0141	73.12	10.01	1	4

Two of the eggs show decidedly high counts. The first, Sample 3006-4, was a winter egg and had probably been held by the farmer or merchant for a long time. The second high count, Sample 4108, was a July egg, and its bacterial condition might be explained by the fact that the shell showed signs of much handling, and the egg had acquired a stale odor. The other samples of the series show low counts; there was an absence of *B. coli* throughout, even in the case of the two high-count eggs.

Six small lots of eggs, where deterioration had gone further than in the type just described, were also examined for bacteria and loosely bound nitrogen. The number of organisms was negligible; the amount of loosely combined nitrogen was higher than had been previously noted. All of these eggs would have been discarded by a careful grader because of the yellow color of the white. Just where to draw the line, however, is not a simple matter. Practical experience would indicate that when the white of the egg was normal in color and when the filaments of yolk were entirely distinct from the white, or when, if the seepage was by the diffuse rather than the localized method, the outer zone of egg white was normal, the bacterial content was low and the loosely bound nitrogen did not rise above 0.0038 per cent.

WHITE ROTS.

If the egg, where white and yolk are just beginning to mix by either method of seepage, be held under commercial conditions, it becomes what is known to egg candlers as a "white rot," or to some as a "sour rot," but the latter is a misleading term and should be discarded. The inexpert or careless candler fails to notice these white rots; hence they are too often found in the breaking room; when opened yolk and white are seen to be completely, or almost completely, mixed. Very frequently the mixture is much thinner than the mixed yolk and white of a fresh egg and may or may not have an offensive odor. Its appearance is never appetizing. Sometimes scraps of membrane are seen, suggesting a disintegrated embryo; again, the contents are thin, homogeneous, and pale yellow (see Pl. VII). The series of eggs given in Table 10 is typical of eggs having these characteristics.

TABLE 10.—White rots (individual eggs).

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Description of sample.
		20° C.	37° C.		
3006-2	Dec. 12, 1910	110,000,000	15,000,000	-----	Pale yellow contents.
3006-3	do	-----	80,000,000	-----	
3012-4	Jan. 14, 1911	0	295	-----	
275	July 3, 1911	5,500,000	3,300,000	0	
495	Aug. 10, 1911	(¹)	(¹)	10,000+	Clean shell; marked shrinkage; movable air cell.
496	do	0	0	0	
497	do	(¹)	(¹)	10,000+	
498	do	120,000	120,000	0	
499	do	0	0	0	
500	do	(¹)	(¹)	10,000+	
4070	Sept. 5, 1911	180,000,000	270,000,000	100+	
4110	Nov. 1, 1911	160	180	0	Shell slightly dirty but fresh looking; stale odor; marked shrinkage; movable air cell.

¹ Innumerable; dilution, 1: 10,000.

The bacterial content in 8 out of the 12 is very high. Two of the eggs were sterile and two of them showed a low count. *B. coli* were looked for 9 times out of the 12 and found 4 times.

The high bacterial content of these white rots is quite in accord with their appearance. Why there should occasionally be a white rot with a low count, as in Samples 3012-4, 498, and 4110, or even a sterile white rot,¹ as in Samples 496 and 499, remains to be explained. Since these white rots seem to be the logical sequence of the mixed egg, they might easily parallel the latter in their bacterial content.

EGGS HAVING YOLK ADHERENT TO SHELL (SPOT ROTS).

The "spot rots" of commerce are eggs in which the yolk has become adherent to one or both of the shell membranes and, perhaps, to the shell itself by means of the membranes. When held before the candle, therefore, the yolk is seen as a distorted, deeply colored mass pressed against some part of the shell (see Pl. IV). As the egg ages in temperatures which are lower than those causing incubation phenomena, the yolk of either the fertile or the infertile egg settles. If the egg is not moved the yolk finally adheres to the membrane against which it rests and it becomes a "spot rot" or, as termed in this report, an egg with the yolk adherent to the shell. If the egg is infertile and ages at such temperatures as prevail in summer time, the yolk frequently rises, presses against the air cell, and finally sticks there. Forty-two such eggs are listed in Table 11. When held before the candle some show no marked characteristics except the adherent yolk. Others show distinct evidences of incubation, general deterioration, cracked shells, etc.

¹ In a dilution of 1 to 10.

TABLE 11.—*Individual eggs with yolk stuck to shell.*

Sample No.	Date of examination.	White.		Yolk.		Number of gas-producing bacteria per gram on plain agar.		Description of sample.
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	White.	Yolk.	
3008-4	1910. Dec. 23	1 100	56					White and yolk stuck to side of shell.
3012-1	1911. Jan. 14	240,000,000	36,000,000	7,000,000	4,300,000			Yolk stuck to shell under dirt spot.
3014-5	Jan. 19			2 1,800	2 280			Dirty shell; yolk stuck to shell under dirt spot.
3014-6	do.			3 280	3 350			Dirty shell.
3017-1	Feb. 3	1 37,000,000						Sour odor on opening.
3017-2	do.				65,000,000			Dirty shell; thin white; yolk stuck near air cell.
3018-1	Feb. 6	0						Slightly dirty shell; yellowish white.
3018-3	do.	0						Dirty shell.
3018-4	do.	0						Dirty shell; yellowish white.
3021-1	Mar. 21	0	0					
3021-2	do.	0	0					
3022-1	Mar. 24	9	9					
3025-7	Apr. 6	0	0					
4001	June 2	1 50	10			1 0		Thick shell; decided hatch spot.
4002	June 12	20	30					Yolk stuck near air cell.
4007	do.	0	0	0	10	0	0	Yolk stuck to shell and broken; marked shrinkage.
4009	do.	20	10	0	30	0	0	Yolk stuck but not broken; badly shrunken.
4019	June 28	0	0	0	0	0	0	Yolk stuck near air cell.
4020	do.	0	0	0	4 0	0	0	Badly shrunken; firm air cell.
4021	do.	(5)	(5)	57,000,000	67,000,000	0	0	Enlarged hatch spot; marked shrinkage; movable air cell.
4022	do.	0	0	0	0	0	0	Yolk stuck to bottom of shell; shook loose; watery white; marked shrinkage; movable air cell.
4023	do.	20	20	25	20	0	0	Yolk stuck near bottom of shell; watery white; marked shrinkage; movable air cell.
4024	do.			0	50	0	0	Yolk stuck near air cell; hatch spot enlarged; watery white; marked shrinkage; movable air cell.
4025	June 30	10	10	10	10	0	0	Do.
4028	July 5	240	20	40	10	10	0	Yolk stuck near air cell; enlarged hatch spot; watery white; marked shrinkage; movable air cell.
4030	do.	150,000	97,000	140,000	140,000	10	10+	Dirty shell; yolk stuck near air cell; watery white; marked shrinkage; movable air cell.
								Yolk stuck near air cell; no hatch spot; watery white; marked shrinkage; movable air cell; stale odor on opening.

⁶ Innumerable at 100,000.⁸ 3014-6, 12,000 molds in yolk at 20° C.⁴ 4020, 170,000 molds in yolk.¹ White and yolk mixed.² 3014-3, 38,500 molds, at 20° C.; 350 molds, at 37° C.

TABLE 11.—*Individual eggs with yolk stuck to shell*—Continued.

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar.				Number of gas-producing bacteria per gram in lactose bile.		Description of sample.
		White.		Yolk.		White.	Yolk.	
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.			
4035	1911. July 5	270,000,000	160,000,000	1,100,000	710,000	-----	10	Yolk stuck to side of shell; enlarged hatch spot; watery white; marked shrinkage; movable air cell.
4048	July 11	10	0	70	35	0	0	Yolk stuck near bottom of shell; bad odor on opening; watery pink white; marked shrinkage; movable air cell.
4049	...do....	260,000,000	320,000,000	14,000,000	140,000,000	0	0	Cracked, dirty shell; odor not good on opening; marked shrinkage; movable air cell.
4050	...do....	0	0	20	0	0	0	Yolk stuck near air cell; watery white; no hatch spot; movable air cell; marked shrinkage; good odor on opening.
4051	July 12	0	0	20	0	0	0	Cracked, clean shell; yolk stuck near bottom of shell; good odor on opening; marked shrinkage.
4052	...do....	0	0	0	0	0	0	Clean shell; yolk stuck near air cell; large hatch spot; good odor on opening; watery white; marked shrinkage; movable air cell.
4053	...do....	0	0	-----	-----	0	0	Dirty shell; yolk stuck two-thirds down shell; good odor on opening; no hatch spot, marked shrinkage; movable air cell.
4055	...do....	10	10	-----	-----	10	-----	Clean shell; yolk stuck near air cell; watery white; marked shrinkage; movable air cell.
4056	July 13	20	0	80	40	-----	10	Clean shell; yolk stuck near bottom; shook loose; moderate shrinkage; fixed air cell.
4141	Dec. 14	2,300,000	2,700,000	1,100,000	970,000	0	0	Dirty green-stained shell; yolk stuck but shook loose; weak white; very movable air cell.
4153	Dec. 16	0	0	25	340	0	0	Fecal dirty shell; yolk stuck near air cell but shook loose; no hatch spot; movable air cell; fairly good odor on opening.
4155	Nov. 28	0	0	0	0	0	0	Kept in cold storage for about six months; clean shell; yolk stuck two-thirds from side of shell; movable air cell.
4156	...do....	0	0	0	0	0	0	In cold storage about six months; shell dirty in spots; yolk stuck two-thirds down side of shell; odor not fresh; hatch spot size of quarter; fixed air cell.
4157	...do....	(?)	29,000,000	94,000	71,000	0	0	In cold storage about six months; greasy, stained shell; weak cloudy white; yolk stuck two-thirds down side of shell; bad odor; movable air cell.
4158	...do....	0	0	35	0	0	0	In storage about six months; clean shell; large hatch spot; weak white; bad odor; marked shrinkage; movable air cell.
4159	...do....	0	70	0	10	0	0	In storage about six months; clean shell; yolk stuck two-thirds toward bottom of shell; odor not fresh; one-third shrunken.

1. Innumerable at 10,000.

Nine of the 42 eggs—or 21 per cent—show very high counts, the maximum being 320,000,000 bacteria per gram in the white of Sample 4049. The lowest count in these infected eggs is 150,000 per gram in the white and 94,000 in the yolk. Then there is a sudden drop to 1,800 per gram in Sample 3014-5, and the 18 remaining samples—or 43 per cent—which show bacteria present have so few that they may be neglected for practical purposes. Fourteen samples—or 33 per cent—were sterile in both yolk and white. The organisms in Sample 3012-1 were probably from the dirt spot on the shell against which the yolk had lain. Sample 3017-1 had a sour odor which indicates bacterial contamination in quantity; 3017-2 had a dirty shell; 4030, 4049, and 4157 had objectionable odors on opening; 4141 had a stained shell. Samples 3017-2 and 4021 had no distinctive feature except the adherent yolk.

MOLDY EGGS.

Damp cellars, wet nests, stolen nests, etc., are responsible for the condition of eggs which show, on candling, dense black areas of varying sizes inside the shell. When the eggs are opened these areas are found to be infected with a mold, usually a common green mold, of the *Penicillium* family (see Pl. VI). Such eggs almost invariably have a moldy odor. If the mold spot is small it may not affect the integrity of the egg structure; on the other hand, it may grow to such dimensions that no distinction between yolk and white can be seen.

The products of the growth of the mold may gelatinize the white or liquefy it and may coagulate the yolk into a cheesy mass or render it watery. It is, however, but seldom that a mold in pure culture is found inside an egg; generally bacteria are also present, and sometimes in large numbers. Both the white and the yolk of moldy eggs are apt to be discolored, usually becoming brownish. This color is not always confined to the area of visible mold, but may be diffused throughout, as shown by cultures made from white and yolk remote from the visible infection. These and other characteristics are noted in Table 12, where the results of the examination of 45 individual eggs showing mold visible to the eye are recorded.

TABLE 12.—*Individual moldy eggs.*

Sam- ple No.	Date of exam- ination.	White.			Yolk.						Whole egg.			Number of gas-producing bacteria per gram in lactose bile.	Description of sample
		Total number of bacteria and molds per gram on plain agar.									Whole egg.				
		Bacteria.			Molds.			Bacteria.			Molds.				
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	White.	Yolk.			Mixed.
3007-2	1910. Dec. 21	28,000	34,000	0	0	20,000,000	7	0	0	0	350	9	30	0	Green mold in air cell. White blackened in place against shell.
3007-4	do.										0	22	0	0	
3011-1	Dec. 29	47	23	0	0						0	15	6,600	0	One black mold spot under candle.
3011-3	do.	15	8	54	0										
3011-5	do.	12,000,000	5,500,000												
3011-6	do.	0	0	570	400										
3012-6	1911. Jan. 14										0	0	5,400	130,000	Considerable mold in air cell; white coagulated against shell in places. Considerable mold in air cell. Considerable mold in air cell; dirty shell.
3013-1	Jan. 16												57,000	73,000	
3013-2	do.										360	160	5,300	5,100	
3013-4	do.														Contents of egg moldy where contents of egg were stuck to shell. Badly shrunken egg with mold in air cell; marked shrinkage.
3014-1	Jan. 19										850	630	0	0	White in bottom of egg coagulated by mold; white near air cell plated.
3014-2	do.	540	540	0	0										Small black mold spot.
3014-3	do.										2,500,000	5,000,000	0	0	Green mold in air cell; yolk under- neath mold spot plated; musty odor.
3015-1	Jan. 24					0	9	1,500	0						
3015-2	do.					24	12	36	0						One mold spot inside of shell; white underneath mold spot coagulated. Mold in air cell on one side of egg; white from opposite side plated; considerable shrinkage.
3016-4	Jan. 30	6	13	0	0						320	430	150	32,000	White, wooly mold in air cell; yolk beneath light in color and friable.
3016-6	do.														

TABLE 12.—*Individual moldy eggs*—Continued.

Sam- ple No.	Date of exam- ination.	White.				Yolk.				Whole egg.				Number of gas-pro- ducing bacteria per gram in lactose bile.			Description of sample.				
		Total number of bacteria and molds per gram on plain agar.																			
		Bacteria.		Molds.		Bacteria.		Molds.		Bacteria.		Molds.									
		Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	Incubated at 20° C.	Incubated at 37° C.	White.	Yolk.	Mixed.					
390-1	1911. Nov 15									0	310	38,000	0	0	0	0	Mold covers yolk and is present in spots on inside of shell; yolk stuck to shell; watery white.				
390-2	do.									0	60	12,500	0	0	0	0	Mold covers yolk and inside of shell; yolk stuck in bottom of shell; watery white.				
390-3	do.									0	25	21,000	0	0	0	0	Mold covering one-half area of yolk and present in spots on shell.				
390-4	do.									0	5	0	0	0	0	0	Mold covers yolk and inside of shell; white and yolk mixed.				
390-5	do.									0	5	88,000	0	0	0	0	Mold present in small spots on air cell.				
390-6	do.									0	10	6,000	0	0	0	0	Mold present in spots on yolk only; yolk stuck in bottom of shell.				
390-1 2	Dec. 14											2 900 11,000,000					Yolk stuck in bottom of shell, broken and covered in spots with mold; watery white; movable air cell.				
390-2 2	do.									0	15	72,000	0	0	0	0	Mold spots all over inside of shell and a large spot on yolk which was stuck to shell near the middle of the egg; watery, gassy white; marked shrinkage.				
390-3 2	do.									0	5	43,500	0	0	0	0	Mold covering nearly all of entire yolk and present in spots on adjoining white and also in air cell; yolk stuck on one side of shell near air cell; one-fifth shrunken.				
390-4 2	do.									0	130	26,000	0	0	0	0	Mold covering nearly all of yolk and present in spots on white; yolk stuck in bottom of shell; watery white; movable air cell.				

390-5 2	do								0	0	0	0	0	Mold nearly covering entire yolk and present in isolated spots all over inside of shell; yolk stuck in bottom of shell and broken; cracked shell.
390-6 2	do								0	0	0	0	0	Mold covering entire yolk and present in isolated islands in neighboring white; yolk stuck to side of shell near air cell.

1 Fresh eggs placed in storage in April, 1911; during the period of storage there was a leak in the ice box in the room above. When the eggs were taken out in November many were found to be moldy.

2 Total bacteria and molds.

It is interesting to observe that *B. coli* were found in but 2 of the 45 eggs; that in those cases it was present in small numbers only and then with large numbers of other bacteria. In fact, the mold in Samples 4029 and 4032, respectively, was in the air cell and apparently had not penetrated the egg membrane, though undoubtedly it would have done so in time. It is also of interest to note that the odor of Sample 4029 was putrid and that of 4032 stale; both had yolks stuck to the shell.

Molds, as indicated by the descriptions given in Table 12, may appear in clean and dirty shell eggs. If the shell is dirty, the first visible spot of mold is very often beneath the spot of dirt. Since the mold infections seem to be due almost entirely to shell penetration after laying, one would expect to find the egg—both yolk and white—adhering to the membrane. Such is usually the case if the growth is extensive.

So varied are the visible results upon the egg of the growth of mold inside the shell that much space might be consumed describing individual eggs. The salient points for our purpose, however, are the facts that the eggs which show mold before the candle give a growth of mold when the egg substance is transferred to suitable culture media, and a study of the substance of such eggs shows that the mold is not confined to the area where it is visible, but is commonly diffused throughout both white and yolk. A moldy egg is also likely to show a large number of bacteria present.

BLACK ROTS.

Black rots need but short comment here. They are recorded for comparative purposes only. Table 13 gives the bacterial findings in 10 of them. The odor and appearance, both before the candle and after opening, would exclude their use for any food purpose or even for leather tanning. They could be used for fertilizer.

TABLE 13.—*Black rots—individual eggs.*

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Description.
		20° C.	37° C.		
	1910.				
3007-6	Dec. 21	180,000,000	140,000,000	.....	Thin, watery contents, with bad odor.
3009-5	Dec. 27	49,000,000	7,500,000	.....	Watery contents, with strong odor.
3009-6	do.....	4,200,000,000	6,300,000,000	.....	Watery, olive-green, gassy contents, with bad odor.
3010-1	Dec. 28	120,000,000	33,000,000	.....	Green contents, with strong odor.
	1911.				
3012-3	Jan. 14	.....	790,000,000	.....	Brownish, gassy contents, with bad odor.
4045	July 11	350,000,000	340,000,000	1,000,000+	Black under candle; egg had a bad odor before being opened, and a still worse one afterwards; some shrinkage; fixed air cell.

TABLE 13.—*Black rots—individual eggs—Continued.*

Sample No.	Date of examination.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Description.
		20° C.	37° C.		
4059	1911. July 13	67,000,000	.....	1,000,000	Black under candle; contents were very gassy and had a frightful odor; clean shell; marked shrinkage; movable air cell.
4060	...do....	11,000,000	5,400,000	1,000,000 +	Black under candle; bad odor on opening; clean shell; marked shrinkage; movable air cell.
4087	Oct. 9	660,000,000	180,000,000	0	Black under candle; shell dirty and stained in one spot with a damp feather, underneath which was a mold spot; balance of the egg was a black rot.
4114	Nov. 7	160,000,000	280,000,000	100	Black under candle; strong odor of hydrogen sulphid; inside of shell and shell membrane black; shell not fresh looking; one-third shrinkage.

The maximum bacterial count was 6,300,000,000 per gram; the minimum 5,400,000. *B. coli* were looked for five times and found four times—in very large numbers except in one sample.

COMPOSITE SAMPLES OF EGGS OPENED COMMERCIALY IN THE PACKING HOUSE.

The study of eggs opened aseptically in the laboratory is logically followed by a study of eggs broken commercially in the packing house. For this investigation a large number of samples were taken of the various types of eggs encountered throughout the egg-breaking season of 1912. It was hoped that the laboratory results, together with the characteristic appearance and odor of the different classes of eggs, would give a practical working basis for the grading of eggs used in the preparation of frozen and desiccated eggs.

The commercial conditions under which the eggs were broken are described in the discussion of D, E, and F houses for 1912, in a forthcoming Department of Agriculture bulletin. The method of opening was in brief as follows: The eggs were broken on a sterilized knife edge, the two sections of the shell pulled apart with the thumb and first and second fingers of each hand, and the contents of the egg allowed to drop into a sterile cup. After every infected egg which could be detected by the senses, the operator replaced the knife and cup with sterile equipment and washed and dried her hands. The fingers were kept dry by means of tissue paper or small towels, which were used but once before laundering. By this method the contamination of the liquid egg during the process of breaking was reduced to a minimum.

If the sample consisted of less than 9 eggs, the liquids were poured directly from the cups to a sterile 16-ounce salt-mouthed bottle,

mixed by shaking, and a small portion of the mixture was transferred to a sterile 4-ounce bottle containing pieces of sterile glass; the large sample was for chemical analyses, the smaller one for bacteriological examination. If the specimen represented 9 or more eggs, the eggs were collected in a suitable container and mixed, a bacteriological and a chemical sample being taken. The samples were frozen in a sharp freezer 12 hours or less, packed in chilled, cork-insulated boxes especially constructed for the purpose, and shipped by express to the laboratory, where they arrived hard frozen. About 3 hours were required for transportation from E house and about 12 hours from D and F houses.

The samples were taken on the successive weekly visits made at D, E, and F houses during the season of 1912. A section in each of the tables containing the laboratory results of this research indicates the time and place of sampling. For example, F-5, in Table 14, signifies that the sample was taken on the fifth visit to F house. The number of eggs represented in each sample varied from 4 to 360.

JULY AND AUGUST FIRSTS.

Since strictly fresh eggs are not used in the United States for the preparation of frozen and desiccated eggs, no studies were made of this grade opened under commercial conditions. During the latter part of July and August, however, when receipts are not only light but also low in quality and cheap, eggs commercially graded as firsts are sometimes used to piece out the regular supply of breaking stock. The firsts of the summer and autumn months differ before the candle from the firsts of the spring months in that the former are much more shrunken, the yolks more opaque, and the whites are less firm. Firsts, also commercially termed "storage-packed No. 1 eggs," constituted a large percentage of the breaking stock used in F house during the season of 1912. They were graded from the daily receipts and held in chilled rooms until needed to fill out the regular quota of eggs for the breaking room.

On the last two visits to F house samples were taken of the liquid egg broken from five lots of firsts, each representing 15 dozen eggs (see Table 14). Care was taken during the process of breaking to eliminate all eggs which might have a deleterious effect on the liquid product. For example, from one sample an egg with a green white was discarded and from a second an egg with a broken yolk which at one time had been adherent to the shell. Some of the firsts had cloudy whites, but such eggs were not discarded in the preparation of these samples because laboratory studies proved that they were not infected.

The laboratory data given in Table 14 show that three of five samples contained less than 1,000 bacteria per gram at 20° C. and the other two 25,000 and 92,000, respectively. In three samples *B. coli* were not found and in the remaining two they were present in small numbers. Since the bacteriological findings given in Table 4 indicate that this grade of eggs, when opened aseptically, is practically sterile and contains no *B. coli*, it might be concluded that the organisms found in the samples opened in the packing house were referable, for the most part, to outside contamination and not to the eggs themselves. On the basis of this assumption these results will be taken as a standard of comparison in the succeeding discussion of the bacterial contents of other types of eggs.

The moisture content of four of the five samples of firsts was lower than the amount found in fresh eggs, which result would be expected from the difference in the amount of shrinkage in the two types of eggs. The average percentage of ammoniacal nitrogen, which was taken as the index of protein decomposition, was 0.0020 per cent on the wet basis for summer firsts, compared with 0.0013 per cent for absolutely fresh eggs. These figures show well the difference in quality of the two grades of eggs.

TABLE 14.—July and August firsts.

[15-dozen lots.]

No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Percentage of moisture.
			20° C.	37° C.		Wet basis.	Dry basis.	
		1912.						
4802	F 5	July 22	Less than 1,000	Less than 1,000	10	0.0022	0.0072	69.59
4823	F 5	July 23	25,000	20,000	0	.0020	.0065	69.14
4966	F 6	Aug. 13	Less than 1,000	Less than 1,000	0	.0020	.0074	72.84
4967	F 6	...do....	Less than 1,000	Less than 1,000	100			
4985	F 6	Aug. 15	92,000	1,000	0	.0019	.0068	71.87

SECONDS.

Seconds constitute a large proportion of the eggs used in the frozen and desiccated egg industry. In the spring, before the candling season begins, this grade consists of small, dirty, and over-sized eggs sorted from receipts by inspection. After the first of June, when all incoming eggs are graded according to the condition of the contents, seconds also include shrunken eggs, hatch spots, weak eggs, heavy rollers, etc.

Since dirty shells during the process of opening contribute a special source of contamination to the liquid eggs, this class of eggs is considered separately in this dissertation.

During the interval between May 4 and August 30, 1912, 9 samples of whites, 9 of yolks, and 25 of whole eggs were taken from the product obtained from seconds, the different lots varying in size from 6 to 30 dozen eggs. During the process of breaking care was taken to discard all eggs which, from appearance or odor, were abnormal. The first five samples given in Table 15 under the section devoted to whole eggs, and the first four in the part assigned to whites and yolks, represent the product broken from small and oversized eggs. The maximum count of organisms per gram was 34,000 in the whole eggs and 85,000 in the whites and yolks.

The counts of the product from small and oversized eggs were no higher than those found in the liquid eggs broken from July and August firsts; in fact, the amount of ammoniacal nitrogen in the former was lower. The chemical results show, therefore, that the contents of the spring seconds were fresher than the summer firsts.

The samples taken after June 1, 1912, represent the small and oversized eggs sorted from receipts by inspection and also those showing incipient deterioration as observed by the candle. An observation of the laboratory results in Table 15 shows a general trend toward higher bacterial counts and greater amounts of ammoniacal nitrogen as the season advances.

TABLE 15.—Seconds.

WHOLE EGGS.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Percentage of moisture.	Size of sample.	Remarks.
			20° C.	37° C.		Wet basis.	Dry basis.			
		1912.								
4245	F 1	May 4	300	750	10				15 dozen...	
4249	D 1	May 6	.....	1,199	19	0.0016	0.0048	66.23	do.....	
4259	D 1	May 7	400	150	10				do.....	
4264	D 1	do.....	34,000	400	0				do.....	
4411	D 2	May 27	23,500	17,000	10,000				10 pounds.	
4578	D 3	June 19	600	300	0	.0016	.0059	73.00	6 dozen...	
4633	F 4	June 28	2,500	950	0	.0020	.0068	70.45	do.....	
4694	D 4	July 9	27,500	21,000	1,000	.0021	.0079	73.35	12 dozen...	
4697	D 4	do.....	5,200	300	0	.0021	.0075	71.81	do.....	
4708	D 4	July 10	10,500	9,900	1,000	.0019	.0067	71.84	12 dozen...	
4710	D 4	do.....	3,200	2,100	0	.0015	.0055	72.75	15 dozen...	
4803	F 5	July 22	110,000	93,000	100	.0023	.0083	72.38	do.....	
4833	F 5	July 24	(¹)	4,000	1,000	.0018	.0059	69.39	do.....	
4745	E 6	Aug. 9	850,000	7,000	0	.0023	.0084	72.63	6 dozen...	
4357	F 6	Aug. 12	66,000	38,500	10	.0015	.0050	70.16	30 dozen...	
4372	F 6	Aug. 14	750,000	550,000	0	.0017	.0061	72.30	do.....	
41002	D 6	Aug. 19	2,000	0 in 1,000	0	.0020	.0072	72.31	24 dozen...	
41018	D 6	Aug. 20	600,000	550,000	100	.0018	.0057	68.25	25 pounds.	
41019	D 6	do.....	39,500	24,000	.....	.....	.....	.....	do.....	
41029	D 6	Aug. 21	320,000	270,000	100,000	.....	.....	.....	do.....	
41031	D 6	do.....	500,000	500,000	100	.0017	.0061	72.53	24 dozen...	
41060	E 7	Aug. 26	1,800,000	700,000	10	.0020	.0074	72.98	30 dozen...	
41070	E 7	Aug. 27	3,600,000	1,600,000	10	.....	.....	72.78	do.....	
41086	E 7	Aug. 30	430,000	55,000	100	.0026	.0095	72.56	do.....	

¹ Less than 1,000.

TABLE 15.—Seconds—Continued.

WHITES AND YOLKS.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Percentage of moisture.	Size of sample.	Remarks.
			20° C.	37° C.		Wet basis.	Dry basis.			
		1912.								
4363	F 2	May 2	49,000	1,200	0	.....	.....	.....	15 dozen...	Whites.
4364	F 2	do.....	85,000	1,000	0	.....	.....	.....	do.....	Yolks of 4363.
4403	D 2	May 27	1,600	150	0	0.0004	0.0031	87.10	15 pounds.	Whites.
4404	D 2	do.....	1,200	400	10	.0033	.0072	54.15	.....	Yolks of 4403.
4416	D 2	do.....	60,000	20,000	100	.....	.....	.....	25 pounds.	Whites.
4417	D 2	do.....	15,000	5,000	.....	.....	.....	.....	.....	Yolks of 4416.
4423	D 2	May 28	1,000	1,000	10	.0003	.0023	87.14	10 pounds.	Whites.
4424	D 2	do.....	4,000	2,700	1,000	.0030	.0070	57.45	.....	Yolks of 4423.
4868	D 5	July 30	360,000	330,000	1,000	.....	.....	.....	13 pounds.	Whites.
4869	D 5	do.....	110,000	90,000	(1)	.0037	.0083	55.42	11 pounds.	Yolks of 4868.
4977	F 6	Aug. 14	40,000	40,000	100	.....	.....	.....	20 pounds.	Whites.
4978	F 6	do.....	130,000	130,000	0	.0037	.0087	57.25	do.....	Yolks of 4977.
41005	D 6	Aug. 19	27,000	22,000	1,000	.....	.....	.....	.....	Whites.
41006	D 6	do.....	300,000	180,000	1,000	.0029	.0067	56.66	15 pounds.	Yolks of 41005.
41011	D 6	do.....	600,000	650,000	0	.0003	.0023	86.96	18 pounds.	Whites.
41012	D 6	do.....	650,000	600,000	0	.0030	.0065	53.64	13 pounds.	Yolks of 41011.

¹ Less than 100.

The lowest number of bacteria found at 20° C. was 300 per gram in a sample taken during the early part of May, and the highest, 3,600,000, in a specimen obtained during the latter part of August. Of the 16 samples of whites and yolks none contained over 650,000 bacteria per gram; of the 24 lots of whole egg only about 8 per cent had more than 850,000. There were no *B. coli* in 14, or 35 per cent, and 100,000, or less, in the remaining samples. The percentage of ammoniacal nitrogen varied from 0.0015 per cent on the wet basis in spring seconds to 0.0026 per cent in summer seconds.

A larger number of eggs was discarded while breaking the summer and fall seconds than when opening analogous eggs in the spring.

It is probable that the organisms in the samples of liquid egg from seconds are referable partly to outside sources, but chiefly to the eggs themselves.

EGGS HAVING DIRTY SHELLS.

The highest percentage of dirty-shell eggs occurs during the wet spring weather. Since they do not keep well in storage, a large number find their way to egg-breaking establishments.

Table 16 gives the laboratory findings of six samples taken during May, June, and August, 1912. Fifteen dozen eggs were represented in one specimen and 6 dozen in the other five. All of the eggs were candled before opening. The number of eggs discarded during the process of breaking gives, perhaps, an index to the quality of the eggs in the different samples. Not more than three decomposed eggs were eliminated from the samples taken during May and June and not more than six from the two specimens broken in August.

TABLE 16.—*Eggs having dirty shells.*

[6 to 15 dozen lots.]

No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Per cent of moisture.	Size of sample.
			20° C.	37° C.		Wet basis.	Dry basis.		
		1912.							Dozen.
4279	D 1	May 8	550,000	500,000	1,000				15
4576	D 3	June 20	400	400	10	0.0017	0.0065	73.85	6
4581	D 3	do.	13,000	3,000	1,000	.0017	.0063	72.87	6
4634	E 4	June 28	700,000	3,300	1,000	.0019	.0068	72.18	6
4947	E 6	Aug. 9	49,000	(1)	10,000	.0023	.0082	71.81	6
41087	E 7	Aug. 30	1,600,000	1,700,000	10	.0023	.0084	72.74	6

¹ Less than 1,000.

The bacterial contents were widely divergent; the minimum number was 400 and the maximum number 1,600,000 per gram at 20° C. The number of *B. coli* varied from 10 to 10,000 in the six samples. The amount of loosely bound nitrogen was markedly higher in the August samples than in the June samples.

Sample 41087 represents about the lowest quality of dirty eggs used by reputable breakers for food purposes. The shells were so filthy that dirty "dirties" (the trade designation) best describes them. The candle showed that they were shrunk eggs, and that many yolks floated near the shell as if they were about ready to adhere to it. The eggs eliminated during the process of opening were highly infected, as follows: One egg with a green white, one sour egg, one egg with yolk nearly mingled with white, and two eggs each with a broken yolk which had at one time been adherent to the shell. The conditions found in this lot of eggs are typical of low grade fall receipts.

The bacteria found in this series of samples were, without doubt, referable both to contamination from the shells during the process of opening and to the eggs themselves.

EGGS HAVING CRACKED SHELLS.

On account of the heavy losses accruing from shipping eggs having cracked shells, these eggs constitute one of the important classes used for breaking purposes.

During the interval between May 2 and August 26, 1912, 2 samples of whites, 2 of yolks, and 16 of whole eggs were taken. These samples represented lots of from 6 to 30 dozen cracked eggs, procured in D, E, and F houses, where it was the custom to keep "checks" in cool surroundings from the time of receipt until the time of breakage, and to give them precedence over other eggs in regard to promptness in candling and breaking. The laboratory results (see Table 17) from these samples indicate what is to be

expected from cracked eggs that are broken in the first concentrating center.

TABLE 17.—*Eggs having cracked shells.*

WHOLE EGGS.

Number.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammonia, nitrogen, Folin method.		Per cent of moisture.	Size of sample.	Remarks.
			20° C.	37° C.		Wet basis.	Dry basis.			
4215	F 1	May 2	600,000	600,000	0	0.0017	0.0056	70.28	15 dozen..	
4216	F 1	..do..	600	1,000	0	.0014	.0046	70.98	..do.....	
4242	F 1	May 3	500,000	300,000	10,000	.....	.....	.....	11 dozen..	
4254	D 1	May 6	750,000	490,000	100	.0016	.0052	69.14	15 dozen..	
4314	E 2	May 14	230,000	80,000	10,000	.....	.....	.....	12 dozen..	
4557	D 3	June 17	340,000	120,000	10,000	.0015	.0052	71.20	30 pounds.	
4572	D 3	June 19	140,000	75,000	0	.0019	.0071	73.22	6 dozen..	
4597	E 4	June 24	460,000	330,000	10	.....	.....	.....	13½ dozen..	
4635	E 5	June 28	2,800	800	0	.0019	.0070	72.82	6 dozen..	
4711	D 4	July 10	700	400	10	.....	.....	.....	15 dozen..	
4827	F 5	July 24	2,200,000	1,800,000	10	.0021	.0068	69.02	..do.....	
4963	F 6	Aug. 13	35,000	35,000	10	.0018	.0065	72.51	..do.....	
4965	F 6	..do..	2,700,000	2,400,000	1,000	.....	.....	.....	..do.....	
4993	F 6	Aug. 16	50,000	38,500	1,000	.0018	.0065	72.29	..do.....	
4994	F 6	..do..	190,000	120,000	100	.....	.....	.....	..do.....	
41032	E 7	Aug. 26	2,300,000	950,000	1,000	.0023	.0074	69.01	30 dozen..	

WHITES AND YOLKS.

4218	F 1	May 2	36,500	1,400	100	0.0002	0.0016	87.36	30 pounds.	Whites.
4219	F 1	..do..	6,800	700	100	.....	.....	.....	..do.....	Yolks of No. 4218.
4282	D 1	May 8	13,500	15,000	1,000	.....	.....	.....	25 pounds.	Whites.
4283	D 1	..do..	25,000	64,000	1,000	.....	.....	.....	..do.....	Yolks of No. 4282.

Although the variation, shown in Table 17, in the number of bacteria in the different lots of cracked eggs was almost the same as that found in the samples of seconds, the individual counts in many instances were higher. For instance, 43.8 per cent of the samples of checks, as compared with 66.6 per cent of the samples of seconds, had counts under 200,000 per gram. The damaged shell of the checks offers less resistance to bacterial invasion than do sound shells, which factor explains the higher average count of cracked eggs. As was the case with the types of eggs previously discussed, the samples with the highest bacterial content were those which were taken during the month of August. The samples showed no greater deterioration chemically than did the specimens of summer firsts, seconds, and dirties.

Eggs with incipient odors but normal in appearance are very often found in some lots of cracked eggs, particularly in those which have not been chilled previous to opening. An examination of four single eggs gave counts of 12,000 bacteria per gram or less in three samples and of 1,200,000 in the fourth. There was no abnormality in the latter to distinguish it from the other three. A fifth sample

composed of five eggs with a similar but not strong odor contained 550,000 bacteria per gram and showed the low amount of ammoniacal nitrogen of 0.0016 per cent on the wet basis. Further tests are necessary before it can be positively stated whether the faint odor of warm cracked eggs is due to bacterial action or to absorption from surrounding materials. Experienced egg breakers recognize the characteristic odor of warm checks and do not discard them.

Quite different were the results of the examination of two individual eggs, the odor of which was suggestive of the products of bacterial growth. The eggs, normal in appearance, differed from each other only in the intensity of the odor. The count of the egg with the faint odor was 12,000,000, of the one with the strong odor 150,000,000. These eggs would be detected by careful grading and eliminated from a food product.

On account of the damaged shell, checks in a short time become infested with bacteria or molds or both. This result is hastened when the shells are soiled with the leakage from other eggs. From different lots of cracked eggs there were selected six samples consisting of from 4 to 12 eggs with moldy shells. No eggs were included unless the contents were normal in appearance, taste, and odor. Table 18 shows that there was a count of 160,000 in one sample and of from 1,200,000 to 12,000,000 in the other five. These results prove that even if the contents of cracked eggs with moldy shells smell, taste, and look good the egg substance is infected with bacteria as well as with molds.

TABLE 18.—Cracked eggs with moldy shells opened commercially in packing house.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Per cent of moisture.	Size of sample.	Description.
			20° C.	37° C.			Wet basis.	Dry basis.			
4217	F 1	1912. May 2	1,200,000	1,300,000	10	230,000	0.0019	0.0062	69.31	8 eggs..	Odor and taste good.
4241	F 1	May 3	2,700,000	1,700,000	10	15,000	.0013	.0043	68.26	12 eggs..	Do.
4398	D 2	May 27	4,000,000	3,100,000	100	9 in 1,000	.0019	.0058	67.17	8 eggs..	Odor good.
4583	D 3	June 20	8,600,000	5,400,000	100	49,000	.0021	.0070	70.18	4 eggs..	Do.
4596	E 4	June 24	12,000,000	5,900,000	0	0	.0025	.0088	71.76	.....	Do.
41022	D 6	Aug. 20	160,000	140,000	1,000	.....	.0019	.0064	70.23	6 eggs..	Do.

MOLDY CRACKED EGGS COMPARED WITH NONMOLDY CRACKED EGGS.

41036	D 6	Aug. 21	22,000,000	13,000,000	100,000	.....	0.0023	0.0078	70.39	11 lbs...	Moldy shells.
41037	D 6	Aug. 21	2,700,000	1,700,000	.....	.....	.0022	.0079	72.09	48 lbs...	Nonmoldy shells from same lot as 41036.

On one occasion a few cases of checks, a large percentage of which had moldy shells, were received at D house. The eggs for breaking were separated into two parts, one consisting of about 13 dozen moldy eggs and the other of about 60 dozen nonmoldy eggs. Every effort was made to eliminate all eggs abnormal in appearance or odor. On account of the number of times that it was necessary to wash hands and to change apparatus after bad eggs, it was a laborious task to separate the good from the bad. For example, there were 3 eggs with a bad odor, 4 rots, 5 sour eggs, and 14 eggs with a green white that were eliminated from the moldy lot. There were, as given in Table 18, 2,700,000 organisms in the nonmoldy and 22,000,000 in the moldy eggs. The quantity of ammoniacal nitrogen was practically the same in the two specimens, and was no higher than that found in some samples of summer firsts, seconds, and dirties. These results show that either the bacteria had not been present long enough or had not multiplied to a sufficient extent to materially change the composition of the egg substance.

The laboratory data from both the large and small samples show that for the preparation of a food product with a low bacterial content cracked eggs with moldy shells should be omitted.

EGGS HAVING THE YOLKS PARTIALLY MIXED WITH THE WHITES.

The class of eggs having the yolks partially mixed with the whites consists of three forms: One in which the yolk has seeped through the vitelline membrane in sufficient quantity to give a yellow tinge to the thick portion of the albumen; the second in which the yolk streams through small openings in the membrane into the white; and the third in which the yolk membrane breaks and allows the yolk to flow into the albumen. The first form can not be detected by the candling process; the second and third in many cases can be recognized by this method. During warm weather the vitelline membrane becomes thin and the white less viscous, which condition, accompanied by the jars occurring during transportation, causes the membrane to break and the contents of the yolk to escape. The cause of the seeping yolk in eggs is not understood. The three forms are the predecessors of the class of eggs called white rots, or eggs with white and yolk entirely mixed.

During the season of 1912, 10 samples, consisting of from 1 to 8 eggs, with yolks seeping into white were taken. The odor and taste of each were good. The results are shown in Table 19.

TABLE 19.—*Small samples of eggs with the yolks beginning to seep into the whites.*

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Percentage of moisture.	Size of sample.
			20° C.	37° C.			Wet basis.	Dry basis.		
		1912								Eggs.
4194	E 1	Apr. 25	2,600	3,900	0	0 in 10,000	-----	-----	-----	3
4251	D 1	May 6	67,000	21,000	100	0 in 10,000	0.0017	0.0062	72.61	8
4266	D 1	May 7	100	400	0	-----	-----	-----	-----	1
4290	D 1	May 9	22,000,000	21,000,000	0	0 in 10,000	.0021	.0077	72.58	5
4357	E 2	May 17	100,000	21,000	10	900,000	-----	-----	-----	2
4406	D 2	May 27	44,000	5,000	0	0 in 10,000	.0020	.0076	73.76	5
4428	D 2	May 28	300	100	0	-----	-----	-----	-----	2
4895	D 5	Aug. 2	3,900,000	3,500,000	0 in 100	-----	.0023	.0078	70.54	5
41001	D 6	Aug. 19	0 in 10,000	0 in 10,000	0 in 100	-----	-----	-----	-----	1
41032	D 6	Aug. 21	17,000	7,500	10	-----	.0018	.0072	74.98	4

Table 19 shows that the number of bacteria varied from 100 per gram at 20° C. to 100,000 in eight samples and from 3,900,000 to 22,000,000 in the other two. No explanation can be given of the cause of the last two counts other than that they may represent transitional stages between yolks beginning to mix and those entirely mixed with white. It was shown on page 30 that the latter are heavily infected with organisms. There were no *B. coli* in one-half of the specimens and only a few in the remaining half. The amount of protein deterioration was no greater than that found in seconds and cracked eggs.

Only three samples were taken of eggs with the yolk entering the white through small apertures in the vitelline membrane. The specimens consisted of individual eggs and were practically sterile.

During the latter part of July two samples were taken, consisting, in one case, of 30 dozen eggs, and in the other of 11 dozen, which, before the candle, appeared to have broken yolks but were otherwise normal. On opening the eggs it was found that the grading by the candle was not accurate, because among them was a large number of eggs which were approaching the stage of white rots. The large sample was opened without much care in grading; the smaller one was broken, and every egg which appeared to have passed the first stage of physical degeneration was eliminated. The difference between the laboratory results of the two samples was striking. The poorly graded sample contained 8,300,000 bacteria per gram, 1,000,000 *B. coli* per gram, and 0.0028 per cent of ammoniacal nitrogen on the wet basis; the well graded one, 5,500 organisms per gram, 10 *B. coli*, and 0.0021 per cent of loosely bound nitrogen. This experiment is a good example of the effect of careful and intelligent grading on a product prepared from doubtful eggs.

These preliminary studies indicate that eggs with yolks showing the first signs of deterioration are suitable for food purposes, if

other characteristics are normal, but that eggs showing more advanced decomposition should be avoided. This phase of the egg problem will be specially investigated during the season of 1913.

BLOODY WHITES.

Many of the first eggs laid by pullets contain blood which may be diffused through the white or may be in the form of clots on the yolk or in the albumen (see Pl. IV). It is probable that in the passage of the white and yolk through the oviduct some of the small blood vessels are ruptured, thereby allowing blood to gain access to the white or yolk before they are incased in a shell.

The examination of six individual eggs of this type disclosed the presence of less than 5,000 organisms per gram. No *B. coli* were found, except in one sample, which had only 10. The eggs were taken from the cups of the breakers; consequently the few organisms found are very likely referable to outside sources and not to the eggs. On account of the presence of blood, these eggs are not used for food purposes.

EGGS WITH BLOOD RINGS.

Eggs showing signs of incubation were discussed quite fully on page 13; consequently only the information gained when these eggs were broken commercially will be given here.

During May, 1912, four samples, consisting of from 3 to 12 large blood rings, were taken. Since the weather had not been warm enough to cause spontaneous development of embryos of fertile eggs, these blood rings were probably the result of the undesirable practice of selling incubated eggs which would not hatch. The yolks were broken and partially mixed with albumen; the germinal disk was deteriorated. The odor of each was good.

TABLE 20.—*Eggs with blood rings.*

LARGE SAMPLES OF EGGS WITH SMALL BLOOD RINGS.

Sample No.	Source.	Date of collection.	Number of bacteria per gram at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Per cent of moisture.	Size of sample.	Remarks.
			20° C.	37° C.		Wet basis.	Dry basis.			
4837	F 5	1912. July 25	36,500	3,500	100	0.0022	0.0077	71.50	30 dozen..	Kept in chill room 2 weeks.
4843	F 5	July 26	37,000	37,000	10	.0022	.0077	71.60	12 dozen..	
4883	D 5	July 31	50,000	41,000	.....	.0019	.0067	71.56	8½ pounds.	
4889	D 5	Aug. 1	¹⁰ in 1,000	¹⁰ in 1,000	0	.0018	.0063	71.58	4 pounds..	
4960	F 6	Aug. 12	950,000	700,000	10,000	.0023	.0074	68.89	30 dozen..	
4975	F 6	Aug. 14	430,000	500,000	10	.0024	.0072	66.58	do	
41033	D 6	Aug. 21	77,000	58,000	0	.0019	.0075	74.59	4½ pounds.	

¹ Less than 1,000.

TABLE 20.—Eggs with blood rings—Continued.

SMALL SAMPLES OF EGGS WITH LARGE BLOOD RINGS.

Sample No.	Source.	Date of collection.	Number of bacteria per gram at—		Number of gas-producing bacteria per gram in lactose bile.	Percentage of ammoniacal nitrogen, Folin method.		Per cent of moisture.	Size of sample.	Remarks.
			20° C.	37° C.		Wet basis.	Dry basis.			
		1912.								
4292	D 1	May 9	1,700	400	0	.....	.....	72.97	3 eggs.....	Broken yolks.
4401	D 2	May 27	100	100	0	0.0014	0.0052	72.97	12 eggs....	Do.
4402	D 2	do.....	400	750	10	.0016	.0059	72.71	do.....	Do.
4430	D 2	May 28	100	150	0	.0019	.0070	72.71	5 eggs.....	Do.
4699	D 4	July 9	7,100,000	400	0	.0018	.0065	72.09	8 eggs.....	Do.

LARGE SAMPLES OF EGGS WITH LARGE BLOOD RINGS.

4838	F 5	July 25	4,000,000	1,900,000	100,000	0.0022	0.0077	71.41	30 dozen..	Kept in chill room 2 weeks.
4844	F 5	July 26	4,300,000	3,100,000	100	.0019	.0068	72.17	9 dozen...	
4884	D 5	July 31	0 in 1,000	0 in 1,000	.....	.0019	.0063	70.00	7½ pounds.	
4888	D 5	Aug. 1	6,500	0 in 1,000	10	.0019	.0063	69.96	10 pounds.	
41040	D 6	Aug. 22	2,000,000	1,400,000	10,000	.0020	.0071	71.98	7 pounds..	

The results of the first four samples given in the second section of Table 20 showed very few organisms and no *B. coli* except in one sample. The amount of ammoniacal nitrogen was identical with that found in contemporaneous samples of seconds, cracked, and dirty eggs. A fifth sample, taken in July, consisting of eight large blood rings, gave a count of 7,100,000 bacteria per gram on agar plates incubated at 20° C. and of 400 on similar plates kept at 37° C. The divergence of the two counts is not explained.

In July and August larger lots of both small and large blood rings were studied. These were caused in part by the warmth of the late summer months and in part by a short period of incubation under broody hens. The first observations were made of a case of blood rings which had been held in a chill room at about 32° F. for two weeks. The eggs were recandled and 8½ dozen eggs with broken yolks or with yolks stuck to the shell were discarded. During the process of breaking, the small and large blood rings were separated, the basis of division being less than 3 centimeters for the small and over that for the large blood rings. Many of the eggs of the former type had firm whites and yolks with faded rings. The eggs with the large blood rings contained broken yolks. All eggs showing signs of mixing of white and yolk, often termed "runny eggs," were excluded. Each lot was mixed thoroughly by passing a few times through a steamed sieve. The resulting mixtures had a good odor. The sample of small blood rings contained 36,500 bacteria per gram; the one

of larger blood rings, 4,000,000. The amount of ammoniacal nitrogen was in each case 0.0022 per cent on the wet basis.

The counts of similar samples of eggs with blood rings which had not been kept for any extended period in a chill room varied from less than 1,000 to 950,000 for small blood rings and from under 1,000 to 4,300,000 for large blood rings. Since the blood rings which were used in these samples underwent the same diversity of conditions before and during marketing as did the seconds, cracked eggs, dirty eggs, etc., they would be expected to show practically the same variations in bacterial contents.

The amount of loosely bound nitrogen in the samples of both small and large blood rings was no greater, and in many cases was less, than that found in stale eggs. These results are in accordance with those found by Pennington and Robertson,¹ which they summarize as follows:

The amount of loosely bound nitrogen in incubated eggs, as determined by the Folin method, shows an interesting change. In the case of infertile eggs a very noticeable and quite regular increase takes place with time, while in the case of the fertile eggs the increase is very slight. Considering the content of loosely bound nitrogen as a criterion of protein decomposition, this is not surprising, since in the first case heat would be expected to increase catabolic processes, making for simpler nitrogen compounds, while in the second case it introduces metabolic or upbuilding processes.

The product obtained from eggs containing small blood rings was normal in appearance, taste, and odor; that obtained from eggs with large blood rings had a much lighter appearance; it was normal with respect to odor but had a flat, insipid, and uninviting flavor. It is evident, therefore, that changes had occurred which were recorded by the senses and not by the examinations just described. Pennington and Robertson found that catalase increased in fertile eggs during incubation, but did not increase in nonfertile eggs held under the same conditions. It may be that the studies now under way on the sugar content of eggs will also throw some light on the changes occurring in fertile eggs during the process of incubation.

EGGS WITH TURBIDITY IN THICK WHITE.

It is observed that when eggs which have been in storage for some time are broken, many of them have a turbidity which is localized in the thick portion of the albumen, but this cloudiness disappears when the eggs are warm. That this is a physical change brought about by low temperatures, and not by bacterial action, is indicated by the results given in Table 21 of the laboratory examination of six samples of eggs with cloudiness in the thick white.

¹ U. S. Dept. of Agr., Bureau of Chemistry Cir. 104.

TABLE 21.—*Eggs with turbidity in thick white.*

INDIVIDUAL EGGS.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Size of sample.	Description.
			20° C.	37° C.				
4571	D 3	1912. June 18	150	650	0	-----	Pounds.	Leaking shell; normal yolk; no odor.
4575	D 3	June 19	43,500	36,500	100	2,000	-----	Do.
4587	D 3	June 22	150	100	0	-----	-----	Opened aseptically.

SMALL SAMPLES.

4598	E 4	June 24	120,000	32,000	10	100,000	4	Cracked eggs; normal yolk; good odor.
4611	E 4	June 25	16,000	500	0	-----	1.5	Cracked eggs and seconds; good odor.
4624	E 4	June 27	290,000	14,000	10	10,000	1	Dirty eggs; good odor.

EGGS HAVING WHITE PARTIALLY COAGULATED BY HEAT.

Breaking-stock eggs are occasionally found with contents which present the appearance of soft-boiled eggs. They probably had been dipped in hot water to prevent their use for hatching when they had been purchased, ostensibly for food purposes. The heat of summer is also, under some circumstances, sufficiently great to cause the albumen of eggs to partially coagulate, thus giving it a clouded appearance. For instance, an egg laid on a haystack exposed to the direct rays of the sun becomes partially cooked and has the appearance of an egg which has been in boiling water about a minute. A bacterial examination of two such eggs showed them to be practically free from organisms.

EGGS HAVING ENTIRE WHITE TURBID.

Bacterial growth in an egg may cause cloudiness in the albumen analogous to that caused by the growth of bacteria in laboratory media. The eggs may or may not have an odor. Eggs with a characteristic sour odor (see p. 61) have, almost invariably, a turbid albumen. An examination of four eggs with a clouded white showed (Table 22) that their bacterial content varied between 15,000 and 150,000,000 per gram. The two eggs with the high counts had an abnormal odor, which fact was indicative of the presence of large numbers of bacteria.

TABLE 22.—*Eggs having entire white turbid.*

[+ denotes presence.]

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Description.
			20° C.	37° C.			
533	F	1911. Aug. 4	5,600,000	3,400,000	100,000	+	Milky white; normal yolk; no odor.
4260	D 1	1912. May 7	13,000,000	8,300,000	100	0 in 10,000	Abnormal odor; normal yolk.
4331	E 2	May 16	150,000,000	120,000,000	10,000	+ in 100,000	Unpleasant odor; cloudy rim of white around yolk.
4766	E 5	July 17	15,000	4,800	100	-----	A very cloudy white; odor and taste good.

WHITE OR LIGHT ROTS.

White or light rots are the advanced forms of partly decomposed eggs, of which the following are typical: Eggs with yolk partially mixed with white, eggs containing old broken-down blood rings, and eggs with a broken yolk which was previously adherent to the shell. Before the candle these eggs are light in appearance, hence their name, and are often passed as good eggs by candlers who do not take the time to determine the condition of yolks. Out of the shell white rots appear as an unappetizing homogeneous mixture of yolk and albumen (see Pl. VII).

During the spring of 1912 six samples, composed of from four to eight white rots, were taken. The condition of these eggs had not been detected by candling, and they therefore found their way to the breaking room. Instead of being consigned to the rotten-egg bucket they were poured from the cups of the breakers into sample bottles. The laboratory examination showed that the majority of the samples were heavily infected with bacteria, among which were many *B. coli*. The results, which are given in Table 23, are in accordance with those obtained in the study of white rots opened under aseptic conditions. The percentage of ammoniacal nitrogen found in five of the six specimens was greater than that found in any of the previous samples discussed. The samples of summer firsts, seconds, checks, and eggs with yolk partially mixed with albumen contained from 0.0014 to 0.0026 per cent of loosely bound nitrogen on the wet basis, whereas the specimens of white rots gave a variation of from 0.0019 to 0.0061 per cent in the amount of ammoniacal nitrogen in five of the six samples examined.

TABLE 23.—*Eggs having the white entirely mixed with the yolk.*

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Percentage of moisture.	Size of sample.
			20° C.	37° C.			Wet basis.	Dry basis.		
		1912.								<i>Eggs.</i>
4261	D 1	May 7	1,100,000	550,000	10	0 in 10,000	0.0025	0.0096	73.27	6
4291	D 1	May 8	14,000	10,000	1,000	0 in 10,000	.0019	.0072	73.63	5
4303	E 2	May 13	82,000,000	60,000,000	1,000,000	37,000,000	.0034	.0111	69.34	4
4318	E 2	May 14	110,000,000	9,100,000	1,000	22,000,000	.0033	.0109	69.68	6
4409	D 2	May 27	16,000,000	5,000,000	10	0 in 10,000	.0027	.0103	73.77	8
4459	E 3	June 1	56,000,000	24,000,000	1,000,000	15,000,000	.0061	.0211	71.17	.....

On account of the large number of bacteria which white rots contain it is very important that breaking stock be candled with sufficient care to prevent these eggs from gaining access to the breaking room.

EGGS HAVING THE YOLK ADHERENT TO THE SHELL.

Two different forms of summer eggs with adherent yolks, termed commercially "heavy spots," were found. One is caused by the action of high atmospheric temperatures and the other by exposure to damp surroundings. In some cases both factors contribute to the same result. Both types occur most frequently during the summer and autumn months.

The heavy spots caused by heat are found in the following stages: First, in which the yolk is so lightly stuck to the shell membrane that a slight jar sets it free (see Pl. VII); the second, in which the yolk is adherent and broken; and the third, in which a very small portion of yolk adheres to the shell, the rest being partially or entirely mixed with albumen. In the case of an incubated fertile egg, it is observed that the adherent surface of the yolk is the hatch spot or blood ring. The first and second types are usually without odor; the third may, or may not, have an odor, and is classed among the white rots on account of the mixing of yolk and albumen.

The eggs with an adherent yolk, produced by moisture, present a characteristic appearance before the candle. The portion of the yolk coming in contact with the shell is dark and often black in appearance. The yolk is much more opaque than normal. When the contents of these eggs are emptied from the shell, a large portion of the yolks cling to the shell. They have commonly a sour or putrefactive odor. This type of egg, if held for a sufficient length of time, may develop mold spots on the yolk.

Three samples with yolk very slightly stuck to the shell were selected by candling. When opened many of the yolks dropped out whole and left no mark on the shell at the place of contact (see

Pl. IV). During the breaking care was exercised to eliminate all eggs showing signs of mixing of white and yolk. For example, from Sample 4842 one egg was discarded; from 4891 twenty-two eggs, and from 4919 a larger number. The number of discards gives, perhaps, an index to the bacterial contents, for, as shown by Table 24, Sample 4842 contained 900,000 organisms per gram; Sample 4891, 8,300,000; Sample 4919, 24,000,000. The amount of ammoniacal nitrogen in the first sample was practically the same as that found in August checks, dirties, and seconds; the quantity in the other two samples was slightly higher. The odor and taste of the liquid product was good in every case.

TABLE 24.—*Small samples of eggs having the yolk adhering to the shell.*

SLIGHTLY ADHERENT.

Sample No.	Source.	Date of collection.	Number of bacteria per gram at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Per centage of moisture.	Size of sample.
			20° C.	37° C.			Wet basis.	Dry basis.		
4842	F 5	1912. July 26	900,000	750,000	100	.....	0.0022	0.0077	71.37	6½ doz.
4891	D 5	Aug. 1	8,300,000	5,800,000	0	.....	.0024	.0083	72.72	4½ lbs.
4919	E 6	Aug. 6	24,000,000	2,700,000	100	.....	.0024	.0086	72.10	1 lb.

HEAVILY ADHERENT.

4422	D 2	May 28	30,000,000	21,000,000	0	0 in 10,000	0.0049	0.0179	72.69	4 eggs.
4841	F 5	July 26	150,000,000	120,000,000	1,000,000	.....	.0031	.0108	71.25	5 doz.

For comparative study two samples of eggs with yolks heavily adherent to the shell and sometimes called by the trade "cellar sticks" were selected by candling. The portion of the yolk which clung to the shell when its contents were emptied was not removed. The product had an abnormal and offensive odor. Table 24 shows that the bacterial counts, as well as the percentage of ammoniacal nitrogen, were higher than those found in the first type, where the yolks were slightly adherent to the shell.

A sample of three eggs with adherent yolks, which had become moldy, contained 7,200,000 bacteria per gram and 0.0022 per cent of ammoniacal nitrogen. If this sample had included "moldy spots" with offensive odors the laboratory results would show much more decomposition.

Further studies will be made of spot eggs. The results cited, however, indicate that these eggs should not be used in a product prepared for food purposes.

BLACK ROTS.

Black rots receive their name from the black appearance which they present before the candle. Out of the shell they are a homogeneous olive green liquid with an offensive odor resembling that of hydrogen sulphid. It is often possible to pick out a black rot from receipts by the odor and grayish tint of the shell. The results of two samples consisting of from four to eight of these rots showed counts of more than a billion bacteria and an amount of ammoniacal nitrogen much greater than that found in any previous type of egg discussed (see Table 25). Black rots, therefore, represent eggs in the last stages of decomposition. Their only value is for fertilizer purposes.

TABLE 25.—*Small samples of black rots.*

Sample No.	Source.	Date of collection.	Number of bacteria per gram at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Per cent of moisture.	Size of sample.
			20° C.	37° C.			Wet basis.	Dry basis.		
4421	D2	1912. May 28	1,100,000,000	310,000,000	10,000,000	99,000,000	.....	.....	72.31	4 eggs.
4873	D5	July 31	2,300,000,000	2,300,000,000	10,000,000	.....	0.0229	0.0800	71.40	8 eggs.

DETERIORATED EGGS NOT DISTINGUISHABLE BY CANDLING.

The eggs previously discussed have been recognizable before the candle or distinguishable by other characteristics, such as dirty or cracked shells. Some eggs, however, which are distinctly undesirable, can not be detected by candling and must be eliminated by the breaker. These are recognized when out of the shell by color, odor, or general appearance. The great majority of them belong to three groups: Eggs having a green white, often called "grass" eggs by the trade; eggs having a pungent, characteristic odor, commonly known as "sour"; and eggs which are "musty," that is, having an odor which is exceedingly penetrating, very characteristic, and often suggesting that of the common jimson weed. This odor increases when heat is applied, so that a single musty egg in 100 pounds of good egg will spoil it for bakers' purposes.

A number of eggs have distinctive odors when out of the shell, though there may be no visible signs of deterioration. Sometimes the eggs absorb these odors, such as the fruity odor which comes when eggs and apples are held in a closed space together, or that of strawboard from the fillers in which they are packed. Unless these absorbed odors carry with them an objectionable taste there would seem to be no reason for discarding the eggs. Other odors, apparently

generated by the chemical changes accompanying deterioration, are indications that the egg is unfit for food.

The various groups of eggs not recognizable before the candle are productive of much trouble in the frozen and dried egg industry. They will therefore be considered separately.

EGGS HAVING GREEN WHITES.

Certain eggs show a distinctly greenish tinge in the white (see Pl. VIII). This may be so slight that it is not noticed unless compared with an egg having a normal color. The majority of these eggs show no other signs of deterioration; others have a thin albumen, a yolk with a ruptured membrane or even mixed to a decided extent with the white. Eggs showing macroscopic evidences of decomposition are usually accompanied by a fetid odor. The shells of eggs having green whites are frequently cracked, stained, or dirty; many have the appearance of washed eggs.

It is of interest to observe that these eggs are found in greatest numbers in the spring, when dirty and wet shells are most prevalent. Being but seldom distinguished by the candler while in the shell, they go to the breakers. Some plants have in the past excluded such eggs when the breaker happened to see them, especially if they had reached the odor stage. Other establishments used them when odorless and gave various reasons to account for the color, the most frequent explanation being that the hen had been eating grass. This supposition led to the term "grass egg" as descriptive of this condition, but as this phrase has been used by the trade to describe the early spring eggs also, much confusion has resulted.

Laboratory examination disclosed the fact that such eggs contain enormous numbers of bacteria, as is shown in Table 26.

TABLE 26.—*Eggs having green whites.*
I. INDIVIDUAL EGGS OPENED ASEPTICALLY.

Sample No.	Source.	Date of collection.	Number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of ammoniacal nitrogen, Folin method.		Percentage of moisture.	Size of sample.	Description.
			20° C.	37° C.			Wet basis.	Dry basis.			
691	B	1911. Sept. 12	220,000,000	3,300,000	1,000,000	.....	.....	.....	.....	.....	Light-green white; no odor. Bad odor. Bad odor; dirty shell.
693	B	Sept. 11	54,000,000	.....	0 in 100	.....	.....	.....	.....	.....	
4145	South.	Nov. 14	5,800,000	1,300,000	0 in 10	.....	.....	.....	.....	.....	
4639	E 4	1912. June 29	35,000,000	1,500	0	0 in 100,000	.....	.....	.....	.....	A cracked egg.

II. INDIVIDUAL EGGS OPENED COMMERCIALY.

631	B	1911. Aug. 31		9,600,000	0 in 1,000						Dirty shell; very green white.
667	D	Sept. 7	7,500,000	10,000,000	0 in 1,000						

III. SMALL SAMPLES OF EGGS WITH LIGHT-GREEN WHITES—ODORLESS—OPENED COMMERCIALY.

WHOLE EGGS.

4817	F 5	1912. July 23	49,000,000	23,000,000	10,000		0.0027	0.0094	71.27	5 pounds.	7 whites. Yolks of 4396. 4 whites. Yolks of 4504.
4818	F 5	do.....	61,000,000	55,000,000	100,000	.....	.0051	.0181	71.86	do.....	
4420	D 2	May 28	320,000,000	100,000,000	1,000,000	3,000,000	.0040	.0136	70.70	7 eggs.	

WHITES AND YOLKS SEPARATED.

4396	D 2	1912. May 27	100,000,000	55,000,000	100,000	20,000,000	0.0007	0.0050	86.04	7 whites.	7 whites. Yolks of 4396. 4 whites. Yolks of 4504.
4397	D 2	do.....	2,700,000	1,800,000	10,000	650,000	.0047	.0104	56.84	Yolks of 4396.	
4304	F 3	June 11	210,000,000	210,000,000	100	30,000,000	.....	.....	.....	4 whites.	
4505	F 3	do.....	26,000,000	4,700,000	0	(1)	.....	.....	.....	Yolks of 4504.	

IV. SMALL SAMPLES OF EGGS WITH GREEN WHITES--ODOR NOT BAD--OPENED COMMERCIALY.

WHOLE EGGS,

[illegible]

WHITES AND YOLKS SEPARATED.

[illegible]

¹ Present in 100,000.

² Spreaders are bacterial colonies which are characterized by their spreading growth on culture media.

The samples given in Part I of Table 26 were opened aseptically. The organisms found are, therefore, referable strictly to the egg. The other samples were obtained in packing houses and were opened into sterile cups. It is possible that a few extraneous organisms may, therefore, be included in these bacterial counts, but the error is small. There is a close agreement between maximum and minimum counts in the samples obtained by the two methods. While but 31 individual commercial samples were examined, many of them represent a large number of eggs and a few approximate 5 pounds each. Twenty-six of the 31 samples, or 83.9 per cent, show counts of over 10,000,000 per gram.

The predominating organism has been found to be *Pseudomonas synchyanea* (Migula)¹ and the color of the egg white is due to the ability of this form to produce a diffuse, green fluorescence in the medium in which it grows. When pure cultures of this pseudomonas were injected into a fresh egg the white assumed the characteristic color in a few days and later developed a fetid odor.

The pseudomonas is not, however, in pure culture when occurring in eggs with a green white. *B. coli*, as well as other organisms, are generally found with it. The numbers of *B. coli*, as determined by lactose bile fermentation, varied from 10 to 1,000,000 per gram.

The eggs which were physically in good condition and odorless, and some of which were separated into white and yolk, are listed in Table 26, Part III. Others, having an odor but not sufficient to preclude use according to old methods of grading, are given in Part IV. It will be observed that the white of the egg has a much greater number of organisms than the yolk, though the infection in the latter is also extensive. A further indication of a mixed infection is the fact that organisms which liquefy gelatin are commonly present in numbers. The pseudomonas isolated does not liquefy gelatin. It does not grow to any extent at 37° C.; yet the counts at this temperature are frequently decidedly higher than the sum of the number of liquefiers and the organisms developing in lactose bile with gas production. Apparently, therefore, these eggs with green-colored whites are recognized by the characteristic color produced by one species, though they are the harbingers of a number of species as well as of great numbers of organisms.

This argument is reenforced by the amount of loosely bound nitrogen found. When the egg is not separable into white and yolk the amount of nitrogen is uniformly high—much higher than in eggs commonly used for food. When the degeneration of the egg is not sufficient to interfere with its physical integrity the amount of loosely bound nitrogen is not materially increased. It might

¹ This organism was identified by Evelyn Witmer, of the staff of the Food Research Laboratory.

be inferred from these facts that even though the number of bacteria in the egg be very high, as, for example, in Sample 4504, where 210,000,000 per gram were found, the infection is too recent to have produced chemical changes in the nitrogenous constituents. Because of the mixed infection it is not possible to correlate the amount of loosely bound nitrogen with the presumably greater or lower number of pseudomonas individuals, since the accompanying organisms may exercise even greater activity in splitting protein molecules.

SOUR EGGS.

The term "sour eggs," or "sour rot," is used by the egg breaker to describe an egg that has when opened a peculiar pungent odor. In the sense of a vinegar or common acid odor these eggs, in the earlier stages at least, do not fit the name. In the later stages they may have an odor suggesting sourness in the usual acceptance of the term. They are characterized by causing a prickling sensation in the nose, suggesting the bite of pepper, though not so sharp nor so well defined. These eggs can not be distinguished by candling. Generally, however, there is some visible sign of degeneration as well as the characteristic pungency. For example, sour eggs frequently have a turbidity in the white, or the yolk membrane may be weak, or even broken, so that the yolk is more or less mingled with the white. The only means of detecting such an egg is the peculiar pungent odor.

Table 27 gives the bacterial and chemical analyses of 18 samples of sour eggs. The samples vary in size from 2 eggs to 5 pounds. All were obtained from the current egg supply in the several packing houses, were broken by cracking on a sterilized knife edge, and were emptied into a sterilized glass cup. The grading was such that the eggs in one lot were as nearly identical as possible.

TABLE 27.—*Sour eggs.*
I. SMALL SAMPLES OF EGGS WITH FAINTLY SOUR ODOR.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of am-mo-niacal nitro-gen, Fol-lin method.		Per cent of mois-ture.	Size of sample.	Description.
			20° C.	37° C.			Wet basis.	Dry basis.			
4427	D 2	1912. May 28	430,000,000	430,000,000	10,000,000+	4,400,000	0.0038	0.0141	73.00	2 eggs.....	White and yolk intact. Do.
4460	E 3	June 1	89,000,000	73,000,000	1,000,000+	.....	0.0052	0.0194	73.19	5 eggs.....	Soft yolks.
4530	F 3	June 13	380,000,000	440,000,000	10,000	.....	0.0032	0.0113	71.57	5 pounds.....	
4815	F 5	July 23	140,000,000	97,000,000	1,000,000+	.....	0.0030	0.0122	75.48	do.....	
4816	F 5	do.....	160,000,000	130,000,000	10,000,000+	.....	0.0046	0.0151	69.52	2½ pounds.....	
4836	F 5	do.....	130,000,000	120,000,000	1,000,000+	.....					

II. SMALL SAMPLES OF EGGS WITH DISTINCTLY SOUR ODOR.

WHOLE EGGS.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of am-mo-niacal nitro-gen, Fol-lin method.		Per cent of mois-ture.	Size of sample.	Description.
			20° C.	37° C.			Wet basis.	Dry basis.			
4256	D 1	May 6	800,000,000	350,000,000	1,000,000+	1,000,000	0.0098	0.0323	69.70	5 eggs.....	White intact; some yolks broken, others soft.
4262	D 1	May 7	270,000,000	170,000,000	1,000,000+	16,000,000	0.0400	0.0141	71.66	do.....	Do.
4281	D 1	May 8	170,000,000	85,000,000	1,000,000	6,000,000	0.0043	0.0153	71.91	6 eggs.....	Peculiar turbid white; some yolks broken, others soft.
4288	D 1	May 9	98,000,000	130,000,000	1,000,000+	50,000,000	0.0029	0.0102	71.47	.....	
4321	E 2	May 14	300,000,000	230,000,000	1,000,000+	8,000,000	0.0036	0.0125	71.19	6 eggs.....	Partially curdled white; soft yolk.
4330	E 2	May 15	200,000,000	180,000,000	1,000,000+	(1)	0.0038	0.0130	72.11	7 eggs.....	
4343	E 2	May 17	70,000,000	11,000,000	1,000,000+	18,000,000	0.0029	0.0102	71.52	8 eggs.....	

WHITES AND YOLKS SEPARATED.

Sample No.	Source.	Date of collection.	Total number of bacteria per gram on plain agar incubated at—		Number of gas-producing bacteria per gram in lactose bile.	Gelatin liquefying organisms per gram.	Percentage of am-mo-niacal nitro-gen, Fol-lin method.		Per cent of mois-ture.	Size of sample.	Description.
			20° C.	37° C.			Wet basis.	Dry basis.			
41016	D 6	Aug. 19	320,000,000	160,000,000	10,000,000+	.....	0.0005	0.0037	87.07	8-10 eggs.....	Whites.
41017	D 6	do.....	160,000,000	92,000,000	10,000,000+	.....	0.0034	0.0075	54.91	do.....	Yolks.

III. INDIVIDUAL EGGS WITH DECIDEDLY SOUR ODOR.

² 4289	D 1	May 7	1, 200, 000, 000	160, 000, 000	1, 000, 000 +	50, 000, 000	.....	.....	.....	.....	A sour and yeasty odor; some white intact, yolk broken.
4338	E 2	May 17	600, 000, 000	6, 500, 000	1, 000, 000 +	(1)	.....	.....	.....	.....	A sour and yeasty odor; white and yolk mingled.
4757	E 5	July 16	410, 000, 000	240, 000, 000	1, 000, 000 +	.....	.....	.....	.....	.....	

Present in 1,000,000.

² Yeast cells present.

All the samples examined show a high count of bacteria. One sample (4269) has more than a billion organisms per gram and all the samples but three have more than 100,000,000. On the score of numbers of bacteria these eggs rank with black rots. The table gives first a series of eggs in which the odor is but faint and which might easily be passed by the careless or too rapid grader. Part II gives another series in which the odor was distinct and Part III gives three samples in which the odor was pronounced. It will be noted that these last three samples are individual eggs, and that a physical deterioration in two of the three has proceeded so far that the vitelline membrane has ruptured.

The bacterial content of the eggs with a faintly sour odor and those with a distinctly sour odor is about the same, with the exception of Sample 4256, in which the bacterial count agrees with the eggs in Part III in having a decidedly sour odor.

The great number of organisms invariably present is, however, the noteworthy feature. Aside from the numbers of organisms, the *Bacillus colon* was found in every sample examined, a condition which, up to this time, has not been observed for any other single type of deteriorated egg. Not only are *B. coli* present, but the number, as determined by lactose bile fermentation, is usually at least a million, and may be 10 million. In some of the samples listed as showing a million, more may have been present, because the dilutions were not made beyond this point. Had they been it is quite probable that the coli organisms would have been found to be more numerous than the analyses indicated. One sample (41016) was separated into whites and yolks. The count in the whites is double that in the yolks, which may indicate an infection from the exterior, though more work must be done with the two portions of the egg before accepting this suggestion as a fact.

Where organisms liquefying gelatin were sought they were found and in comparatively large numbers. Hence, there is in these eggs a condition very much like that noted in the eggs with a green white, namely, a mixed infection aggregating large numbers of individual organisms and characterized by the presence of one distinguishing species.

The amount of loosely bound nitrogen is higher than that commonly observed in seconds, which, on the average, is 0.0067 per cent on the water-free basis. The range, omitting Sample 4256, which is exceptionally high, is from 0.0102 to 0.0194 per cent, with an average of 0.0134 per cent, all these values being on the water-free basis. The water content of the samples varies from 69.52 to 75.48 per cent, indicating a decided variation in the age of the eggs as measured by shrinkage.

MUSTY EGGS.

The eggs called musty by the bakers have a strong odor, very penetrating and persistent, becoming more pronounced when heat is applied. All such eggs are sharply watched for by egg breakers and discarded. Fortunately they are not very plentiful, even in the early spring and late summer, when they are most common. Hot, dry weather seems to lessen their frequency.

Sometimes several musty eggs will be found in the same lot; very rarely almost a whole case of eggs will be of this type. They can not be recognized by the candler and very frequently there is no physical sign to indicate that the egg is not good. The sense of smell alone must be depended upon to detect them.

The few examinations made of musty eggs do not justify any conclusions; therefore they are not given here. It is highly desirable that further and detailed studies be made of this type of egg, which is interesting from practical and scientific viewpoints.

SUMMARY.

BACTERIOLOGICAL RESULTS OF INDIVIDUAL EGGS OPENED ASEPTICALLY IN THE LABORATORY.

The first section of Table 28, summarizing the total bacterial contents of individual eggs opened aseptically in the laboratory, shows that the greatest percentage of second-grade food eggs examined, the medium stale eggs, hatch-spot eggs, heavy rollers, dirty eggs, cracked eggs, and eggs with yolk partially mixed with albumen, contained less than 1,000 bacteria per gram. The occasional high bacterial content of single cracked eggs, dirty eggs, etc., could, in most instances, be predicted by the appearance of the shell or by the odor and condition of the contents. Such eggs would ordinarily be recognized and discarded by the housewife or egg breaker.

The second section discloses the rather unexpected fact that *B. coli* were not present in the whole-shelled second-grade eggs and were present in only 5.9 per cent of the cracked-shelled eggs.

Blood rings and the last five types of eggs given in the two sections represent eggs ordinarily discarded as unfit for food purposes. The first section shows that 26.5 per cent of the eggs with adherent yolks, 50 per cent of the eggs with dead embryos, 75.9 per cent of the moldy eggs, 66.7 per cent of the white rots, and 100 per cent of the black rots contained over 1,000 organisms per gram. A review of the second section of the table shows that, with the exception of the white and black rots, *B. coli* were present in but few of the eggs.

TABLE 28. Summary of bacteriological results of individual eggs opened aseptically in the laboratory.

NUMBER OF ORGANISMS PER GRAM.

Type of egg.	Portion of egg examined.	0 to 10, inclusive.		11 to 100, inclusive.		101 to 1,000, inclusive.		1,001 to 10,000, inclusive.		10,001 to 50,000, inclusive.		50,001 to 100,000, inclusive.		100,001 to 500,000, inclusive.		1,000,001 to 5,000,000, inclusive.		5,000,001 to 10,000,000, inclusive.		10,000,001 and over.		Total.
		Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	Num-ber of sam-ples.	Per cent. sam-ples.	
Medium stale eggs.	White.	7	77.7	2	22.2																	9
	Yolk.	9	100.0																			9
	Whole egg.	4	36.4	6	54.5	1	9.1															11
Hatch spot eggs.	White.	4	50.0	2	25.0	2	25.0															8
	Yolk.	2	22.2	6	66.6	1	11.1															9
	Whole egg.	6	75.0	1	12.5	1	12.5															8
Small blood rings.	White.	5	62.5	1	12.5	2	25.0															8
	Yolk.	3	33.3	6	66.6																	9
	Whole egg.	7	53.7	2	15.4																	27
Cracked eggs.	White.	7	25.8	14	53.7	2	7.5	1	3.8													26
	Yolk.	6	23.0	13	50.0	4	15.4															28
	Whole egg.	6	21.4	17	63.7	4	14.2															26
Heavy rollers.	White.	3	50.0	3	50.0																	6
	Yolk.			3	100.0																	3
	Whole egg.	22	88.0																			25
Dirty eggs.	White.	23	44.1	14	27.4	7	13.7	4	7.8													51
	Yolk.	9	25.6	12	31.2	8	22.8	4	11.4													35
	Whole egg.	8	47.1	7	41.1																	17
Eggs with yolk partially mixed with white.	White.																					35
	Yolk.	22	62.9	5	14.3	1	2.8															29
	Whole egg.	8	27.5	9	31.0	2	6.9	1	3.4													4
Eggs stuck to shell.	White.	1	25.0	1	12.5	3	37.5	1	12.5													8
	Yolk.																					17
	Whole egg.																					13
Eggs with dead embryos.	White.	4	23.5	3	17.6	2	11.7	2	11.7	1	5.9											17
	Yolk.																					13
	Whole egg.	2	8.3	1	4.2	2	8.3	4	16.5	6	25.0	3	12.5	2	8.3	1	4.2					24
White rots.	White.	2	16.6																			12
	Yolk.																					10
	Whole egg.																					10
Black rots.	White.																					443
	Yolk.																					443
	Whole egg.																					443
Total.		137		154		45		18		9		11		15		11		14		29		443

NUMBER OF GAS-PRODUCING ORGANISMS PER GRAM IN LACTOSE BILE.

Type of egg.	Portion of egg examined.	0		10		100		1,000		10,000		100,000		1,000,000		Total number of sam- ples.
		Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	
Medium stale egg.	White	3	100.0													3
	Yolk	3	100.0													3
	Whole	3	100.0													3
Hatch spot eggs.	White	9	100.0													9
	Yolk	9	100.0													9
	Whole egg	5	100.0													5
Small blood rings.	White	7	100.0													7
	Yolk	7	100.0													7
	Whole egg	10	100.0													10
Cracked eggs.	White	20	90.9				4.5									22
	Yolk	20	90.9				4.5									22
	Whole eggs.	28	96.5													29
Heavy rollers.	White	6	100.0													6
	Yolk	5	100.0													5
	Whole	35	100.0													35
Dirty eggs.	White	35	100.0													35
	Yolk	35	100.0													35
	Whole egg	14	100.0													14
Eggs with yolk partially mixed with albumen.	White	22	91.6				8.3									24
	Yolk	22	88.0				12.0									25
	Whole egg	2	100.0													2
Eggs with dead embryos.	White	7	87.5													8
	Yolk	6	75.0				12.5									8
	Whole egg	5	83.3				16.7									6
Moldy eggs.	White	13	100.0													13
	Yolk	5	35.5													9
	Whole	1	20.0													5
White rots.	White	1	20.0													5
	Yolk	1	20.0													5
	Whole	1	20.0													5
Black rots.	White	1	20.0													5
	Yolk	1	20.0													5
	Whole	1	20.0													5
Total.		299		6		6		1		4		2		3		321

1 No higher dilution made.

BACTERIOLOGICAL AND CHEMICAL RESULTS OF COMPOSITE SAMPLES OF EGG OPENED COMMERCIALY IN THE PACKING HOUSE.

The laboratory results of composite samples of eggs opened commercially in the packing house are summarized in Tables 29 and 30 and are shown graphically in figures 1 and 2. From these data the following conclusions are drawn:

(1) The samples of July and August firsts contained very few organisms, and in many cases no bacteria of the *B. coli* group.

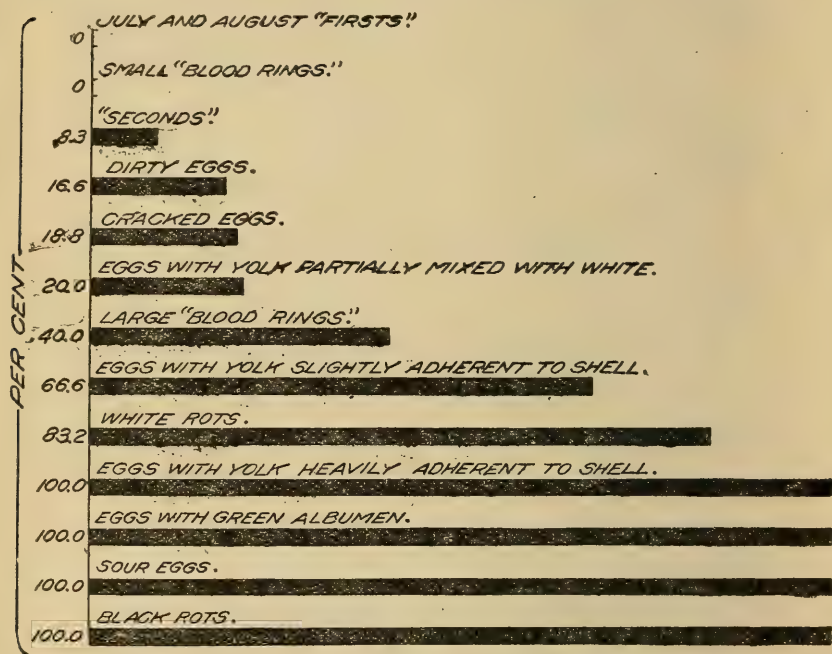


FIG. 1.—Percentage of samples opened commercially with bacterial counts over 1,000,000 per gram.

(2) The majority of the samples of clean-shelled seconds had a comparatively low bacterial content, only 8.3 per cent of them containing over 1,000,000 organisms per gram. The number of *B. coli* varied in the different specimens from none to 100,000 per gram.

(3) The percentage of bacterial counts over 1,000,000 per gram in samples of dirties, checks, and eggs with yolk partially mixed with albumen was 16.6, 18.8, and 20 per cent, respectively. No greater number of *B. coli* was found in these samples than in samples of seconds.

(4) The samples of blood rings contained comparatively few organisms. The large blood rings in most instances showed more infection than did the small rings. Most of the specimens contained less than 10 *B. coli* per gram.

(5) The amount of protein decomposition as shown by the ammoniacal nitrogen in the preceding six types of eggs was greater, as would be expected, than that found in strictly fresh eggs, but was no greater than that found in some grocery eggs. Although a cracked

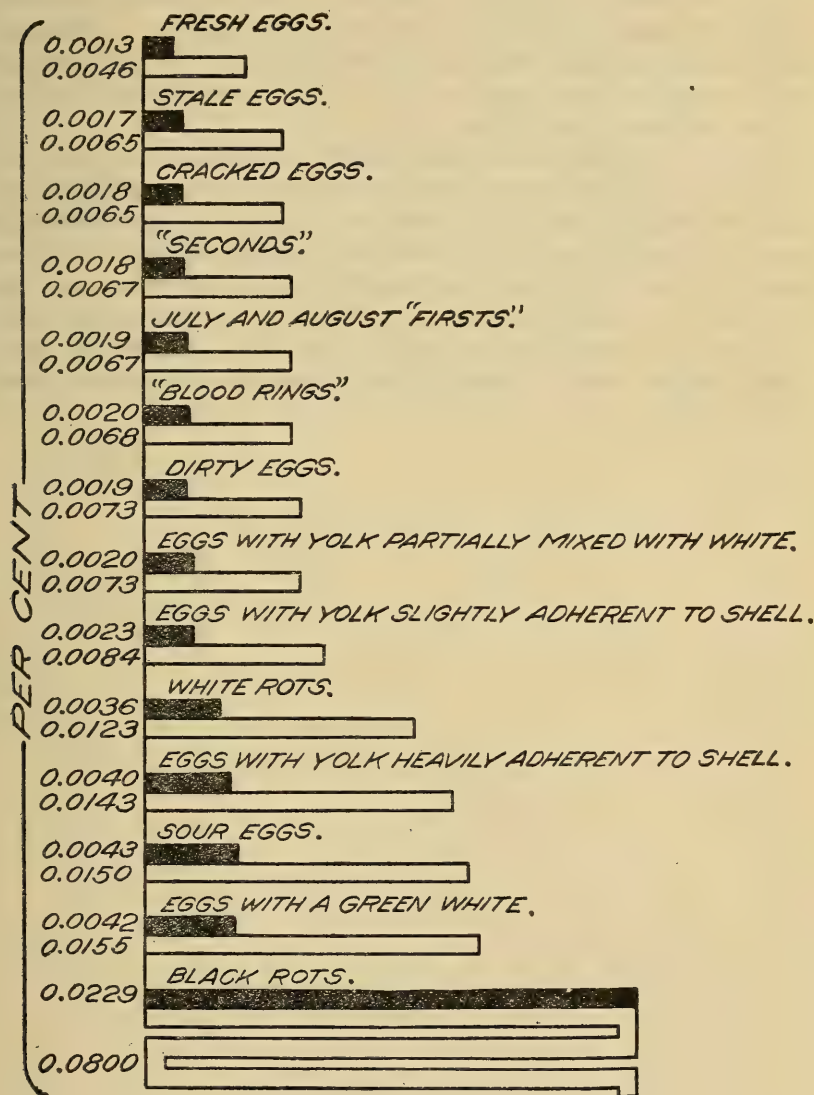


FIG. 2.—Average amount of ammoniacal nitrogen in 14 types of eggs (closed bars, fresh basis; open bars, dry basis).

or dirty shell may be a factor in facilitating infection and subsequent decomposition, the data obtained show that checks and dirties in the producing section are as well preserved as the clean whole-shelled seconds or the July and August firsts.

(6) The eggs constituting the samples of July and August firsts, seconds, dirties, and checks would be used without compunction by the housewife, baker, or confectioner.

(7) The majority of the samples of white rots, eggs with yolk lightly adherent to the shell, and all of the samples of sour eggs, black rots, eggs with a green albumen, and eggs with yolk heavily adherent to the shell, were infested with bacteria. *B. coli* were present in most of these samples, forming the predominating organism in the samples of sour eggs.

(8) The eggs with the yolk lightly adherent to the shell were, chemically, slightly lower in quality than were the second-grade food eggs, whereas the sour eggs, white rots, eggs with a green white, and eggs with yolk heavily adherent to the shell showed much more deterioration. Black rots had five times as much ammoniacal nitrogen as any of these types of eggs. With the exception, possibly, of the eggs with yolks lightly stuck to the shell, none of the eggs in these samples would be used by the housewife or reputable baker or confectioner.

TABLE 29.—*Summary of bacteriological results of eggs opened commercially in the packing house.*

I. TOTAL NUMBER OF ORGANISMS PER GRAM.

Type of egg.	0 to 10,000, inclusive.		10,001 to 50,000, inclusive.		50,001 to 100,000, inclusive.		100,001 to 500,000, inclusive.		500,001 to 1,000,000, inclusive.		1,000,001 to 5,000,000, inclusive.		5,000,001 to 10,000,000, inclusive.		10,000,001 and over.		Total number of samples.	Total number of dozens examined.
	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.	Num-ber of sam-ples.	Per-cent.		
July and August firsts.....	3	60	1	20	1	20	4	16.6	3	12.5	2	8.3					5	75
Seconds.....	9	37.5	5	20.8	1	4.2	6	37.5	2	12.5	3	18.8					24	429
Cracked eggs.....	3	18.8	2	12.5													16	244
Cracked eggs with moldy shells.....							1	16.6	2	33.3	2	33.3	1	16.6	2	33.3	6	14
Dirty eggs.....	1	16.6	2	33.3							1	16.6					6	45
Eggs with yolk partially mixed with white.....	4	40	2	20							1	10			1	10	10	3
Small blood rings.....	1	14.3	3	42.8	1	14.3	1	14.3	1	14.3	3	30	1	10			7	119
Large blood rings.....	6	60															10	67
Eggs with yolk slightly adherent to shell.....									1	33.3	1	33.3	1	33.3			3	12
Eggs with yolk heavily adherent to shell.....																		
White rots.....			1	16.6							1	16.6			2	100	2	5
Eggs with a green white.....													4	19	17	68.6	4	3
Sour eggs.....															18	80.9	21	52
Black rots.....															2	100	18	15
																	2	1
Total.....	27		16		5		12		9		14		7		46		136	1,084

TABLE 29.—*Summary of bacteriological results of eggs opened commercially in the packing house—(continued).*

II. NUMBER OF GAS-PRODUCING ORGANISMS PER GRAM IN LACTOSE BILE.

Type of egg.	0.		10.		100.		1,000.		10,000.		100,000.		1,000,000.		10,000,000 and over.		Total number of sam- ples.
	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	Num- ber of sam- ples.	Per cent.	
July and August firsts.....	3	60	1	20	1	20											5
Seconds.....	8	34.8	6	26.1	4	17.4	3	13.1	1	4.3	1	4.3					23
Cracked eggs.....	4	25	4	25	2	12.5	3	18.75	3	18.75							16
Cracked eggs with moldy shells.....	5	62.5	2	25	1	12.5											8
Dirty eggs.....			2	33.3			3	50	1	16.6							6
Eggs with yolk partially mixed with white.....	5	62.5	2	25	1	12.5											8
Small blood rings.....	2	33.3	2	33.3	1	16.6			1	16.6							6
Large blood rings.....	4	44.4	2	22.2	1	11.1			1	11.1	1	11.1					9
Eggs with yolk slightly adherent to shell.....	1	33.3			2	66.6											3
Eggs with yolk heavily adherent to shell.....	1	33.3			1	33.3											3
White rots.....	2	33.3			2	33.3							1	33.3			6
Eggs with a green white.....	1	5.9	1	5.9	1	3.9	2	11.7	7	41.2	1	6.9	4	23.5	15	93.8	17
Sour eggs.....									1	6.2					2	100	16
Black rots.....																	2
Grand total.....	36		22		17		11		15		5		5		17		128

TABLE 30.—*Variation in amount of ammoniacal nitrogen in 17 types of eggs.*

Kind of eggs.	Number of samples.	Per cent of ammoniacal nitrogen, Folin method.	
		Wet basis.	Dry basis.
Fresh eggs.....	6	0.0011-0.0015	0.0040-0.0054
July and August firsts.....	4	.0019-.0022	.0065-.0074
Grocery eggs.....	10	.0010-.0022	.....
Stale eggs.....	3	.0016-.0018	.0061-.0069
Seconds.....	17	.0015-.0026	.0048-.0095
Cracked eggs.....	18	.0014-.0024	.0046-.0083
Cracked eggs with moldy shells.....	7	.0013-.0025	.0043-.0088
Dirty eggs.....	14	.0013-.0024	.0061-.0084
Eggs with yolk partially mixed with white.....	5	.0017-.0023	.0062-.0078
Small blood rings.....	7	.0018-.0024	.0063-.0077
Large blood rings.....	9	.0014-.0022	.0052-.0077
Eggs with yolk slightly adherent to shell.....	3	.0022-.0024	.0077-.0088
Eggs with yolk heavily adherent to shell.....	2	.0031-.0049	.0108-.0179
White rots.....	6	.0019-.0061	.0072-.0211
Eggs with green whites.....	12	.0016-.0071	.0056-.0264
Sour eggs.....	12	.0029-.0098	.0102-.0323
Black rots.....	1	.0229	.0800
Total.....	136	.....	.....

A COMPARISON OF BACTERIAL CONTENTS OF INDIVIDUAL EGGS OPENED ASEPTICALLY WITH THOSE OF EGGS OPENED COMMERCIALY.

A comparison of the results of individual eggs opened aseptically with the results of composite samples of eggs opened under clean commercial conditions shows some apparent discrepancies. For instance, only 4, or 7.1 per cent, of the 56 individual cracked eggs opened aseptically contained over 1,000 organisms per gram, whereas 14, or 87.5 per cent, of the 16 composite samples, representing 2,924 "checks," opened commercially contained more than this number per gram.

It will be observed that the numbers of the latter are far in excess of the former; it will be remembered, also, that eggs vary greatly among themselves. It is possible, therefore, that the differences between the bacterial findings of individual eggs and composite samples are due, in large part, to the relative difficulty in detecting early stages of infected eggs.

It was possible, for instance, to detect by the senses¹ but two of the four individual cracked eggs which were infected. It has been shown in Tables 26 and 27 that incipient sour eggs, which are detected only by the sense of smell, and eggs with albumen just beginning to turn green, which are recognized only by the sense of sight,

¹ To determine definitely to what extent it is possible to detect infected eggs by means of the senses, and to what extent the bacterial content of a product consisting of large numbers of eggs of unknown history can be minimized by grading, it is necessary to make detailed descriptions of the characteristics of many individual eggs, to open each aseptically and to determine their bacterial content singly and in combination. To find, also, the amount of bacterial contamination acquired during the preparation, studies must be made of the routine methods in use in egg-packing houses to determine the part which each step in the process of preparation plays in the final condition of the product. This subject will be presented as the second report of this series.

contain millions of organisms. It is reasonable to conclude, therefore, that the earlier forms of such and similar eggs furnish large numbers of bacteria to the liquid product prepared from second-grade food eggs. It is quite probable, also, that these earlier stages of incipient sour eggs are a contributing cause to the presence of appreciable numbers of *B. coli* in liquid egg of good quality.

TECHNIQUE FOR THE BACTERIOLOGICAL EXAMINATION OF EGGS.

METHODS USED FOR OBTAINING SAMPLES OF INDIVIDUAL EGGS OPENED ASEPTICALLY IN THE LABORATORY.

*A. Mercuric chlorid method.*¹—The eggs were washed in running water, treated for five minutes in a 1 to 500 or 1 to 1,000 mercuric chlorid solution, and then rinsed with sterile water. The egg was then placed, large end uppermost, in a suitable holder. A small opening was made in the apex with sterile, fine-pointed forceps, about 2 square centimeters of the shell removed, and the membrane punctured. About 2 cc of the white were then transferred with a sterile pipette to a sterile tared weighing flask containing small pieces of sterile glass. The opening was made larger and as much of the white as possible removed with the pipette. With a second sterile pipette the vitelline membrane was ruptured, and about 2 cc of the yolk transferred to another weighing flask. When it was impossible to examine white and yolk separately, on account of disintegration, a sample of whole egg was taken.

*B. Flaming method.*²—The egg was washed in running water, rinsed in sterile water, dried with a sterile towel, and placed, large end uppermost, in a suitable holder. The top of the egg was sterilized by flaming. A portion of the top was removed with fine-pointed forceps and the contents of the egg dropped into a sterile salt-mouthed 4-ounce bottle containing sterile glass.

PREPARATION OF COMPOSITE SAMPLES OF EGGS OPENED COMMERCIALY IN THE PACKING HOUSE.

The details of the collection and handling of the samples are described on page 39. When the samples arrived in the morning, they were examined immediately. When they came late in the day, they were put at once into a sharp freezer and held overnight. On arrival at the laboratory the hard-frozen samples were placed immediately in a water bath at 40° C. and allowed to remain, with frequent shaking, until completely melted. After shaking the melted sample vigorously for five minutes, about 3 cc were transferred with a sterile pipette to a tared weighing flask.

¹ Samples 4001 to 4159, inclusive, and 3001 to 3030, inclusive, were obtained by this method.

² Samples with numbers under 1,000 were obtained by this routine.

METHOD OF PLATING AND COUNTING.

The flask containing the portion for examination was weighed. The weight of egg material in grams multiplied by 9 gave the number of cubic centimeters of sterile physiological salt solution required to make a 1 to 10 dilution, the slight error due to the gravity of the egg material being disregarded. After very thorough shaking, 1 cc of the 1 to 10 dilution was transferred by means of a sterile pipette to 9 cc of sterile physiological salt solution, thereby obtaining a 1 to 100 dilution. Higher dilutions were made on the same plan. Two duplicate series of plates of nutrient agar were prepared from four consecutive dilutions. One set was incubated at 37° C. for two days; the other for five days at 20° C.

The history of the sample was used as a basis for deciding in each case which dilutions should be plated. Whenever possible plates containing from 50 to 250 colonies were selected for counting. The numerical results were expressed in accordance with the rules prescribed by American Public Health Association, 1912. A Stewart's counting chamber and a hand lens, magnifying four or five diameters, were used to facilitate the counting. To determine the sterility of the media, the salt solution, and glassware, blank plates were poured at each plating. Plates of agar were also exposed to the air for three minutes during each plating to show the relative freedom from air contamination.

DETERMINATION OF THE NUMBER OF ORGANISMS CAPABLE OF LIQUEFYING GELATIN.

In a number of the experiments to be reported an attempt was made to determine the gelatin liquefying organisms quantitatively. For this purpose gelatin plates were prepared at the same time and in the same manner as the agar plates. These were incubated at 20° C. and the liquefying colonies counted at the most appropriate time. The counts were so discordant that many of the results were discarded. The difficulty appeared to be due principally to the fact that in most cases there was present a mixture of organisms, some of which were capable of liquefying the entire plate in 48 hours while others required several days, or even weeks, to show the first signs of liquefaction. The action of the slower ones was, therefore, masked by that of the more rapid.

After a large number of gelatin plates had been made and it was found that irregular counts were very frequent, it was decided to abandon the method except in special instances where special information was required.

DETERMINATION OF THE NUMBER OF ORGANISMS PRODUCING GAS FROM LACTOSE IN THE PRESENCE OF BILE SALT.

At the time of plating 1 cc of each dilution was transferred to a Durham fermentation tube containing lactose bile salt medium.

These tubes were incubated for two days at 37° C., at the end of which time each dilution showing gas was recorded as positive. The fermentation tests were in every case started with the 1 to 10 dilution and carried at least one dilution higher than the plating. The denomination of the highest dilution showing positive results was reported as the number of gas-producing organisms in the sample. This is the generally accepted presumptive test for *B. coli* group.

FURTHER EXAMINATION OF THE GAS-PRODUCING ORGANISMS.

As far as time permitted, one of the higher dilutions from each sample showing gas production was plated qualitatively either on litmus lactose agar or Endo's medium. From these plates typical coli-like colonies were selected and examined to ascertain whether they conformed to the definition of *B. coli communis* as given in the 1905 Report of the American Public Health Association. For this purpose they were subjected to the following tests, morphology, Gram stain, motility, liquefaction of gelatin, coagulation of milk, production of indol from peptone solution, reduction of nitrates to nitrites, fermentation of lactose, and fermentation of dextrose. They were then tested for gas production in dulcete, sucrose, mannite, and raffinose, in order to classify them according to the scheme outlined in the 1912 Standard Methods of Water Analysis, American Public Health Association.

CULTURE MEDIA USED.

The nutrient agar, gelatin, and broth were made from fresh beef practically in accordance with the directions given in Standard Methods of Water Analysis, American Public Health Association, except that they were made in larger quantities than there specified and were cleared with egg white and filtered through paper.

The lactose bile salt medium was prepared by dissolving 10 grams of peptone, 5 grams of bile salt (commercial sodium taurocholate), and 5 grams of sodium chlorid in 1 liter of distilled water, filtering and adding 10 grams of lactose.

The sugar broths were prepared by adding 1 per cent of the sugar to neutral sugar-free nutrient broth, made from fresh beef.

The milk was fresh, separator skimmed. It was used both with and without litmus.

ANALYTICAL METHODS USED IN THE "EGG INVESTIGATION" DURING THE SUMMER OF 1912, AT OMAHA, NEBR.

Ammoniacal nitrogen.—Briefly stated, the method consisted in making the egg solution slightly alkaline with sodium carbonate, driving out the ammoniacal nitrogen with a current of air, absorb-

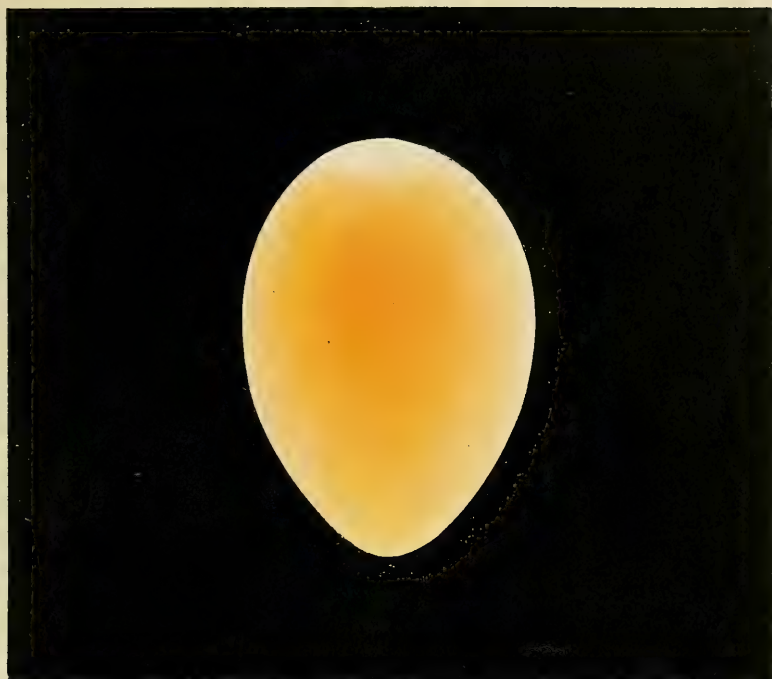
ing the ammonia in standard sulphuric acid, and titrating the excess of the latter with twentieth-normal ammonia solution, using congo red as indicator. For liquid egg, 50 grams were weighed into a liter suction flask, 200 cc of water were added, and the flask violently shaken until a uniform suspension was secured. There was then added in turn 100 cc of 95 per cent alcohol, to prevent foaming, 2 grams of sodium carbonate, to render the solution alkaline, and 1 gram of sodium fluorid as a preservative, the mixture being shaken after the addition of each reagent. The flask was then put in place and aspirated for five hours, using a strong air current. The latter was first drawn through a 25 per cent solution of sulphuric acid to remove ammonia, and was then delivered to the aspirating flask through a tube with several small perforations, thus affecting an excellent distribution of the air current through the egg mixture. It was then passed through a trap which caught any particles carried over mechanically or through foaming, through the absorption flask, which contained 10 cc of twentieth-normal sulphuric acid diluted with 50 cc of water, and finally through a second trap, which retained any acid carried over mechanically. Three hundred cubic centimeter Erlenmeyer flasks were used for the absorption apparatus and traps. From time to time the flask containing the egg mixture was shaken to insure complete removal of the ammonia. After the air current had passed for five hours the apparatus was disconnected, the second trap and connecting tubes were rinsed off into the absorption flask, and the excess of acid titrated with twentieth-normal ammonia solution, using congo red as an indicator. For desiccated eggs 20 grams were weighed into a liter suction flask, 230 cc of water added, and this same process followed.

Moisture.—About 3 grams of egg were weighed into a small lead dish (bottle cap), dried in a water-jacketed oven at 100° C. for one hour, placed in a vacuum oven and dried in vacuo at 70° C. for 10 hours, cooled in a desiccator, and weighed. The sample was then reheated in vacuo until constant or increased weight was noted, weighing at intervals of two hours. The lowest weight obtained was taken as the nearest approximation to the correct figure.

Ether extract.—The lead dish and dried sample from the moisture determination were cut into small pieces, placed in a Johnson extraction apparatus, extracted for 16 hours with anhydrous ether, the ether expelled on the steam bath and the fat dried at 100° C., cooled in a desiccator, and weighed.

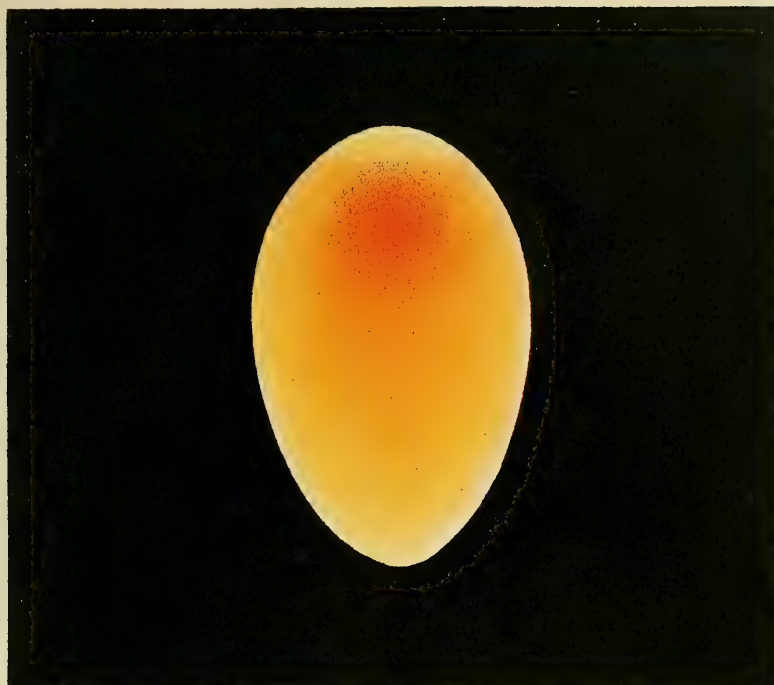
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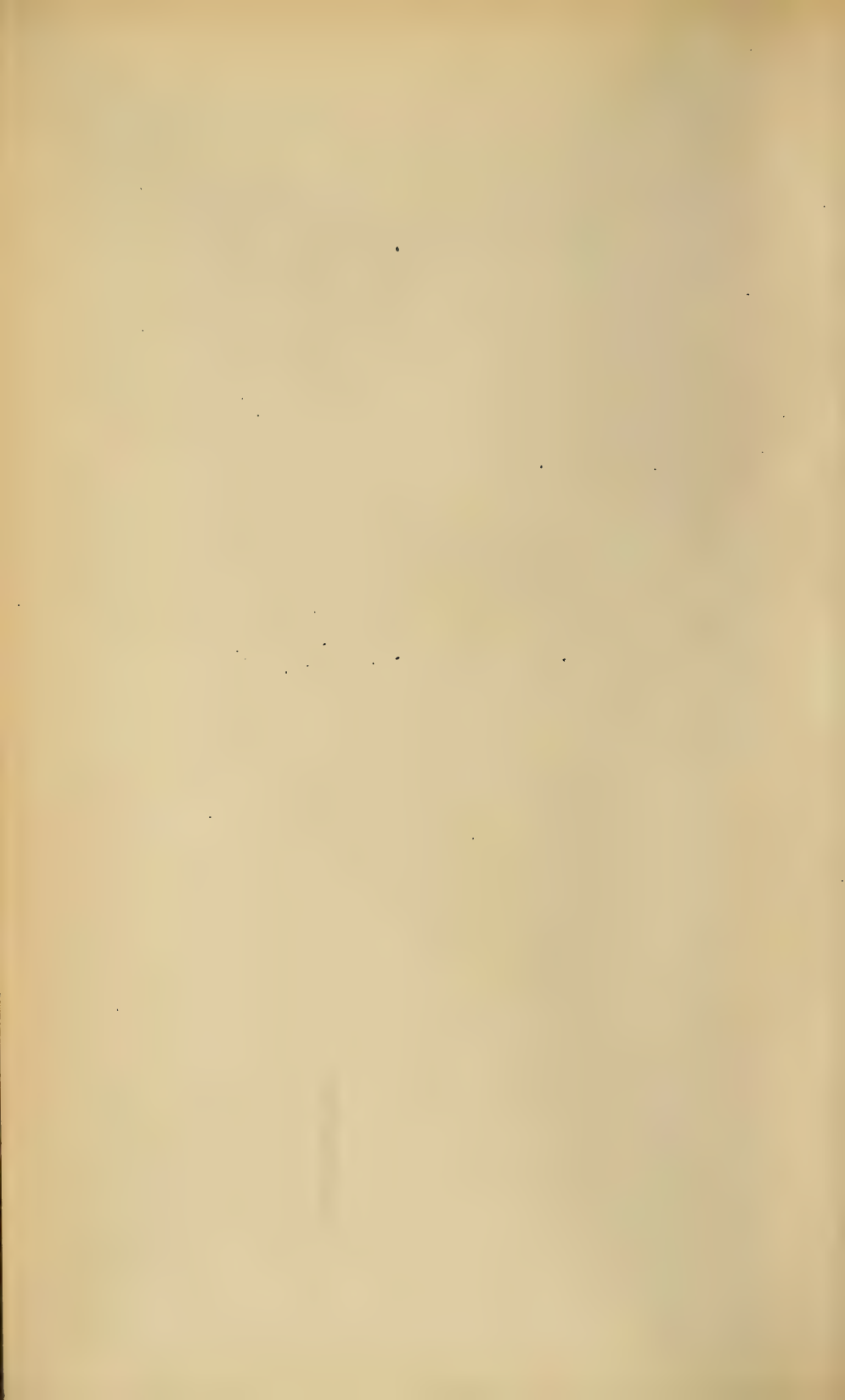
A FRESH EGG BEFORE THE CANDLE AND OUT OF THE SHELL

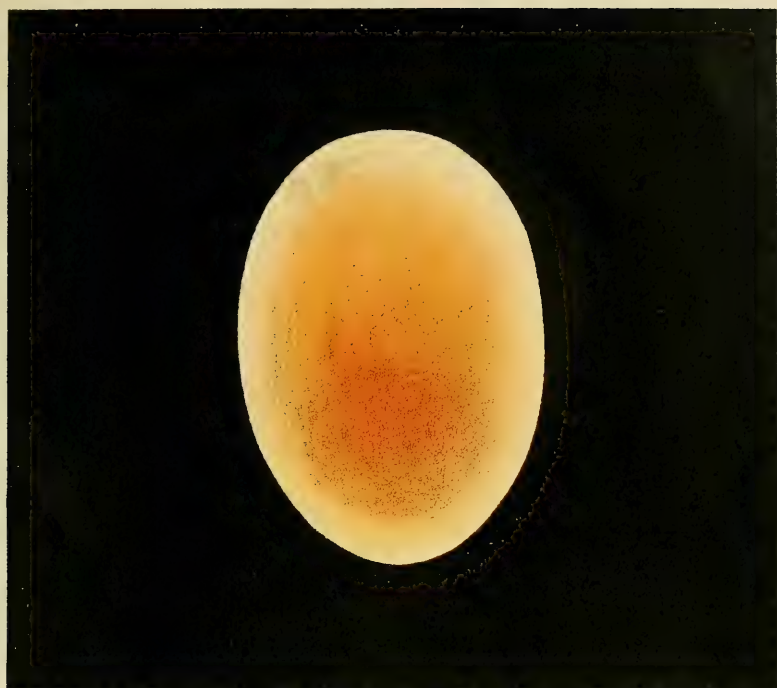


H.M.P. Betts

SLIGHTLY STALE EGG SHOWING EVIDENCE OF INCUBATION
BEFORE THE CANDLE AND OUT OF THE SHELL

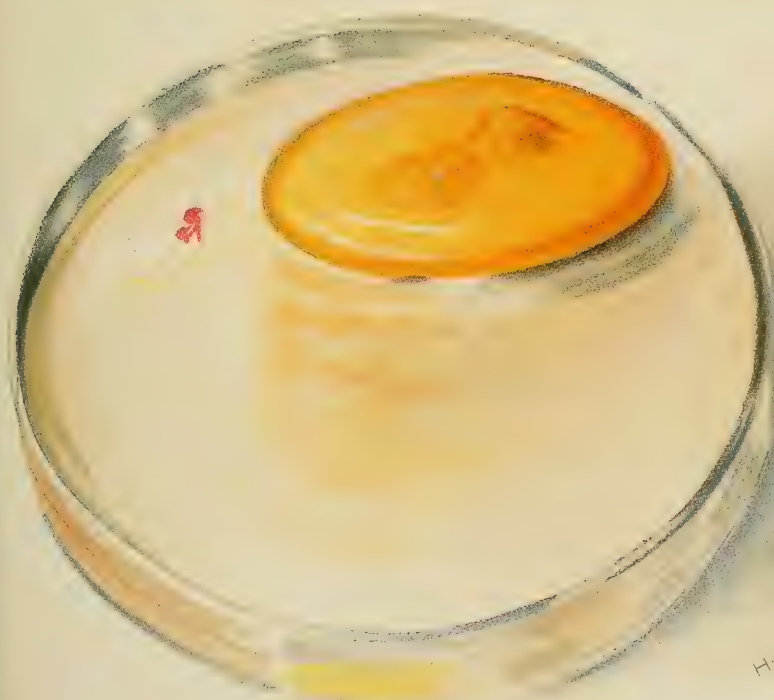
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STALE EGG SHOWING A SETTLED, FLATTENED YOLK AND A THIN WHITE
BEFORE THE CANDLE AND OUT OF THE SHELL



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EGG WITH YOLK BEGINNING TO ADHERE TO SHELL
BEFORE THE CANDLE AND OUT OF THE SHELL

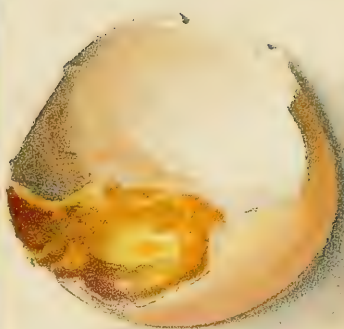
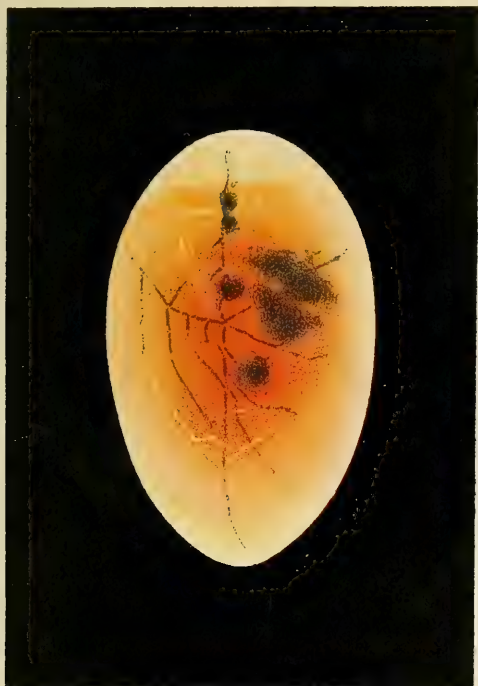
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EGG SHOWING "BLOOD RING"
BEFORE THE CANDLE AND OUT OF THE SHELL

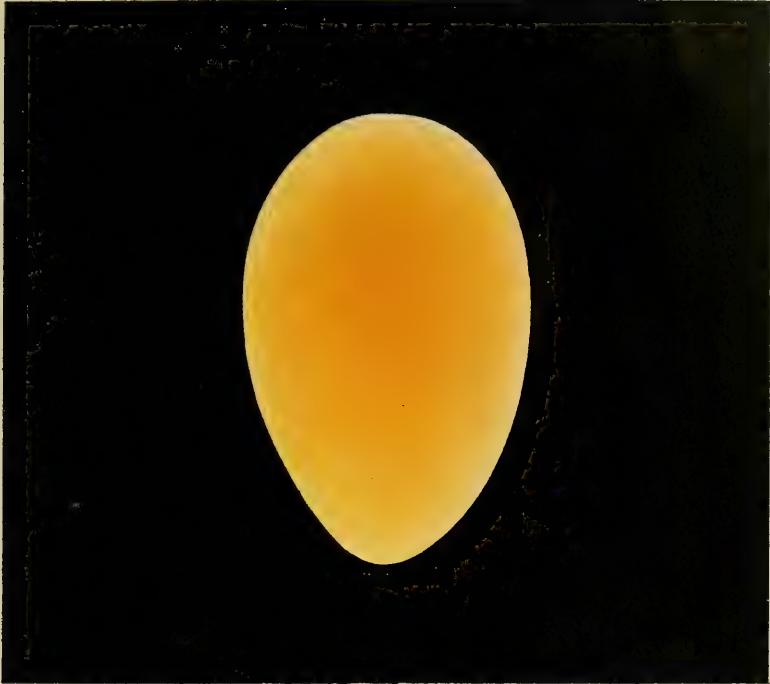
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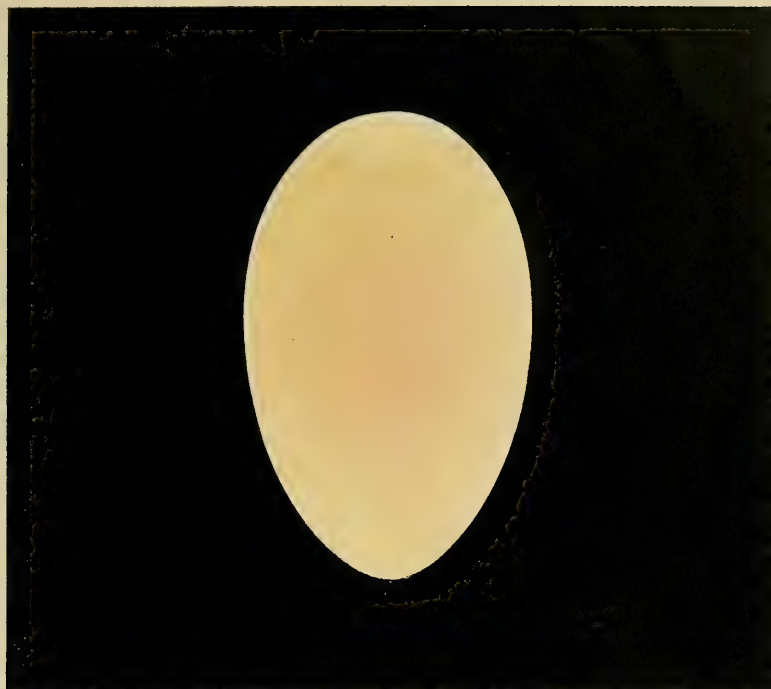
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CRACKED EGG INVADDED BY MOLD
BEFORE THE CANDLE, OUT OF THE SHELL AND THE SHELL SHOWING MOLD INSIDE



WHITE ROT OR ADDLED EGG
BEFORE THE CANDLE AND OUT OF THE SHELL

H.M.P. Belts



H.M.P. Betts

EGG WITH A GREEN WHITE
BEFORE THE CANDLE AND OUT OF THE SHELL



BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 52



Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
January 24, 1914.

THE ANTHRACNOSE OF THE MANGO IN FLORIDA.

By S. M. McMURRAN,

Assistant Pathologist, Fruit-Disease Investigations.

INTRODUCTION.

The growing of mangos in Florida is beginning to assume some commercial importance. With the increase in size and value of the crops, the mango blight or anthracnose has forced itself upon the attention of the growers and a demand has arisen for remedial or preventive measures. The writer was assigned to the investigation of this disease and spent the seasons of 1912 and 1913 in Dade and Palm Beach Counties, Fla., studying the trouble in the field and laboratory.

A careful canvass of the situation was made during the last week of January and the first week of February, 1912, and all the trees and groves that could be located between Key Largo, 40 miles south of Miami, and Palm Beach, 70 miles north, were examined. It was found that practically all of the seedling trees had bloomed heavily during the first two weeks in January, but that none had set fruit. Most of the trees carried the dried peduncles of the January bloom at this time, and many of them remained attached to the trees until the middle of March, at which time a second crop of bloom appeared. Several hundred of these peduncles were collected and many of them while still on the trees showed spores of a fungus in abundance. A number of those that did not show spores were placed in a moist chamber and they all developed spores of the same type in from 24 to 48 hours. At the same time a number of leaves showing small, irregular, grayish spots were collected and placed in moist chambers. In from three to four days these leaves produced similar spores in the diseased areas. Later in the season young shoots that showed black spots were collected and placed in moist chambers. These also produced the same type of spores from the diseased spots. In the latter part of June, as the fruits were ripening, a number were collected, the skins of which were blotched and disfigured, and these likewise produced the same type of spores. (Pl. I.) Portions of

this material were examined by Mrs. Flora W. Patterson, Mycologist of the Bureau of Plant Industry, who pronounced the fungus to be *Colletotrichum gloeosporioides* Penz.

Hawaiian-grown mangos which were affected by this fungus were received by Mrs. Patterson in 1904, and from time to time during the past four years Miss Clara Hasse, of the Office of Fruit-Disease Investigations, has received mango flower clusters, leaves, and fruits from Porto Rico and Florida which were affected by this fungus.

The disease has been reported by several writers. Fawcett¹ says that the trouble was recognized in Florida by officers of the State experiment station in 1893. It has been reported from Porto Rico by Collins,² Hawaii by Higgins,³ Cuba by Cardin,⁴ and Trinidad by Rorer.⁵ Of the aforementioned writers, Higgins and Cardin state that the disease may be controlled by spraying with Bordeaux mixture, but their recommendations are not definite and do not give the times and number of treatments necessary, or the experimental data on which the conclusions are based.

Wester⁶ reports that he has had successful results in preventing the blighting of the blossoms by spraying. His work was done in Florida and will be discussed in another part of this paper.

It is the purpose of this paper to report in detail such data as have been gathered during the past two years in regard to the behavior of the disease and its control, together with an analysis and discussion of the main limiting factor of the mango in Florida.

SOURCE OF INFECTION.

Colletotrichum gloeosporioides is probably one of the most widely distributed pathogenic fungi in the Tropics. In Florida it causes the well-known wither-tip of citrus fruits and is pathogenic on at least several other fruits.

Bessey⁷ has the following to say in regard to its distribution in Florida:

We see, therefore, that it is not a fungus confined to one or two hosts in a limited area, with which we have to contend, but one of wide distribution and capable of attacking a great many kinds of plants. I have found apparently the same fungus on over 50 plants at Miami, some of them common weeds. This explains why, when the weather conditions or other circumstances are favorable, the disease springs up everywhere without any very apparent center of infection.

¹ Fawcett, H. S. Mango. Bloom blight (*Gloeosporium mangiferac*). Florida Agricultural Experiment Station Report, 1906, p. 25. 1907.

² Collins, G. N. The mango in Porto Rico. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 28, p. 20, 1903.

³ Higgins, J. E. The mango in Hawaii. Hawaii Agricultural Experiment Station, Bulletin 12, p. 22, 1906.

⁴ Cardin, P. P. Bloom blight of mango in Cuba. The Cuba Review, v. 8, no. 5, p. 28-29, 1910.

⁵ Rorer, J. B. Annual Report of the Mycologist, Board of Agriculture, Trinidad, p. 7, 1910.

⁶ Wester, P. J. Bordeaux mixture for mangos and avocados. The Florida Agriculturist, v. 34, no. 14, p. 1-2, 1907.

⁷ Bessey, E. A. Report on plant diseases. Proceedings, 21st Annual Meeting, Florida State Horticultural Society, p. 97, 1908.

Beneath mango trees the disease can be found on the fallen leaves and, as previously mentioned, the blighted peduncles frequently remain in situ for many weeks. These produce spores when conditions of moisture are suitable, and when a second bloom follows before they have fallen the conditions for infection are ideal. Even after they have fallen to the ground they may continue to be a source of infection for some weeks. The mango branch illustrated in Plate II, figure 1, was photographed on March 4, 1912, and shows a persistent, diseased peduncle of the January bloom, with the young March bloom appearing around it.

It seems likely that the potential possibilities for infection are very great at all times and that all that is needed is a favorable season as regards moisture to produce the disease in abundance.

It is probable that the spores do not retain their viability for a great length of time. Pedicels showing spores of the fungus were collected the last week in February, 1912. They were kept in an envelope in a laboratory drawer until July 10 of that year, when attempts were made to germinate them in drops of water on glass slides. A number of slides were prepared on several successive days, but no germination was obtained. Inasmuch as the fresh spores germinate readily under such conditions, it is to be inferred that these spores were no longer viable. Under tropical conditions, however, fresh supplies of spores are being continually produced throughout the year.

INFECTION EXPERIMENTS.

Infection experiments were planned to determine whether the flower clusters of the mango could be artificially inoculated with this fungus and whether the results of such inoculation would be similar to the natural infection observed. The experiments were limited in size and should, perhaps, be repeated on a larger scale, but taken in connection with the other facts presented, i. e., the constant association of this fungus and this alone, as no other was found on diseased inflorescences, and the observations of Bessey and Rolfs given later, they seem to be sufficient to remove any reasonable doubt as to the cause of the disease in Florida. A seedling tree in the Subtropical Garden at Miami was selected for this work. Fourteen buds which had just begun to swell were covered on February 26, 1912, with manila paper bags, which were then tied securely around the branches. On March 5 the bags were removed from four buds, which were about 2 inches long at that time. One was sprayed with distilled water with an atomizer, and three with distilled water containing spores of the anthracnose fungus. They were all immediately rebagged. The work was done at 10 o'clock a. m. on a calm day, and no shoot was exposed for more than three minutes. The spores for all the infection experiments were obtained from diseased panicles which had

been naturally infected. On March 10 the three panicles sprayed with spores showed minute dark spots. The control was clean. On March 21 the four panicles were removed from the tree. The control was still clean, while those sprayed with spores were conspicuously marked on the peduncles and pedicels. Those showing disease were placed in a moist chamber, and in two days large quantities of anthracnose spores had oozed out from the infected parts. This experiment was repeated on two other occasions without variation, and the same results were obtained.

Bessey¹ conducted inoculation experiments with this same organism and writes as follows:

Under Prof. Rolfs's direction, before he severed his connection with the Subtropical Laboratory, inoculation experiments were begun, which have been continued, with some interruption, under my direction since I assumed charge of the laboratory. These have demonstrated that this fungus (*Colletotrichum gloeosporioides*) is the same one that causes the blossom blight, leaf spot, and fruit rot of the mango and avocado, the tear staining of the mango, and the leaf spots and fruit rots of various other plants.

SPRAYING EXPERIMENTS IN THE SPRING OF 1912.

It was hoped to determine two points by means of these spraying experiments: (1) Is Bordeaux mixture effective in preventing infection of the flower clusters and fruits, and (2) how frequently and at what times is it necessary to spray to get the best results?

Unfortunately for the success of the work, there are no large groves of mangos in Florida. However, the work was done on as large a scale as was possible, and certain results which will be emphasized in other parts of this paper stand out quite clearly. Bordeaux mixture was the only fungicide used, and it was made according to the 3-5-50 formula in 1912 and the 4-6-50 formula² in 1913. The spraying outfit consisted of a 50-gallon barrel sprayer, half-inch hose, and 9-foot bamboo extension rods equipped with double Vermorel nozzles. The spraying was done under a pressure of approximately 75 pounds to the square inch. With one exception, noted later, no spray injury was observed at any time, and this is significant, as just such conditions existed as might be expected to induce it, i. e., the weather was moist and showery during the first three weeks in which the spraying was conducted.

The experiments were carried on at Mr. Flanders's place, about 2 miles north, and Mr. Roop's place, about 3 miles west, of Miami.

THE EXPERIMENT IN THE FLANDERS GROVE.

The mangos on the Flanders place consisted of a double row of the Mulgoba variety, each row containing 31 trees. They were divided

¹ Bessey, E. A. Op. cit.

² This shows the proportion of copper sulphate (bluestone), lime, and water used in the mixtures.

into 7 blocks, the sprayed blocks alternating with the unsprayed. Block 1 contained 26 trees and the remainder 6 each. Thus, 4 blocks were sprayed and 3 unsprayed. The spraying schedule is shown in Table I.

TABLE I.—*Spraying schedule followed on the Mulgoba mangos on the Flanders place, Miami, Fla., 1912.*

Block.	Dates of spraying.			
	March.	April.	May.	June.
No. 1.....	8, 11, 14, 19	4, 22	13	3, 24
No. 3.....	8, 12, 19	4, 29	27	24
No. 5.....	8, 13, 19	4	6	10
No. 7.....	8, 14, 20	4	13	24

It was planned to spray block 1 every third day, block 3 every fourth day, block 5 every fifth day, and block 7 every sixth day beginning when the buds began to swell and continuing until the flowers had opened. The treatment was suspended at that time, March 19, until the fruit had set, and then resumed. Thereafter the spraying was to be continued at intervals of three, four, five, and six weeks, respectively, until about two weeks before the fruit was to be picked. It will be seen by examining the dates that the spraying prior to the setting of fruit was varied slightly in blocks 1, 3, and 5. This was due to rainy weather.

On June 29 the fruits on all the trees were examined and careful notes made of their condition. Those which showed no blemishes were classed as clean, those but slightly marked as slightly diseased, and the remainder as badly diseased. The fruit counts are shown in Table II.

TABLE II.—*Fruit counts of the Mulgoba mangos in the spraying experiment on the Flanders place, Miami, Fla., 1912.*

Block.	Condition of the fruit.		
	Clean.	Slightly diseased.	Badly diseased.
No. 1 (sprayed).....	10	1	0
No. 2 (unsprayed).....	0	0	1
No. 3 (sprayed).....	71	25	9
No. 4 (unsprayed).....	0	2	11
No. 5 (sprayed).....	7	1	0
No. 6 (unsprayed).....	0	0	0
No. 7 (sprayed).....	12	0	0

The trees in this experiment bloomed lightly and irregularly, and the total number of fruits harvested from each sprayed block is not sufficient to give any definite conclusions in regard to the relative merits of the various spraying schedules; but the fact that considerably more fruit was carried through to maturity on the sprayed than on the unsprayed trees indicates that the protecting of the panicles from

fungous infection was decidedly beneficial. This must not be taken as showing that spraying made the fruit set better, for such was not the case. The fruit set equally well on the unsprayed trees, but the diseased panicles were not able to carry it to maturity.

Of the 136 sprayed fruits harvested, 74 per cent were bright and clean, 20 per cent slightly diseased, and 6 per cent badly diseased. Only 14 fruits were harvested from the unsprayed trees. Of these, 2, or 14 per cent, were slightly marked by the fungus and 12, or 86 per cent, badly diseased.

THE EXPERIMENT ON THE ROOP FARM.

Two seedling trees were used in the experiment on the Roop farm, both of which bloomed heavily. One was sprayed according to the plan used in block 1 of the Flanders experiment. They had both bloomed in January, and at the time of the beginning of the second bloom a number of diseased peduncles were still on the trees. (Pl. III, figs. 1 and 2.) No fruit was set from this January bloom. The dates of spraying are given in Table III.

TABLE III.—*Spraying schedule followed on the seedling mango on the Roop place, Miami, Fla., 1912.*

	Febru- ary.	March.	April.	May.	June.
Dates of spraying.....	29	2, 5, 8, 11, 14	1, 22	13	3

The last spraying, which should have been given on June 24, was omitted because the few fruits which remained on the tree were so badly diseased that it was not thought worth while to spray again. The fruit counts were made on June 29 and were as follows:

TABLE IV.—*Fruit counts of the seedling mangos in the spraying experiment on the Roop place, Miami, Fla., 1912.*

Tree.	Condition of the fruit.		
	Clean.	Slightly diseased.	Badly diseased.
No. 1 (sprayed).....	4	13	37
No. 2 (unsprayed).....	0	0	1

Only one fruit was set on the unsprayed and only 54 on the sprayed tree. The panicles on the sprayed tree showed no sign of disease up to the time of blooming. Most of the blossoms became infected, however, as they opened. The pedicels showed disease as far back as the flowers extended about a week after blooming. These were covered with Bordeaux mixture practically all of the time, but the disease spots developed beneath the covering of the

fungicide.' They did not develop on the peduncles, however, which points very strongly to infection having taken place through the blossoms. The panicles on the unsprayed tree began to show diseased spots on the pedicels and peduncles before their growth in length was more than half complete, and practically all of the blossoms blighted, the one fruit which set being in the extreme top of the tree. Plate IV, figures 1 and 2, shows the typical condition of a blighted panicle as compared with one in full bloom which has not yet developed any sign of the disease.

SPRAYING EXPERIMENTS IN THE WINTER AND SPRING OF 1913.

As during the preceding season, the mangos bloomed quite generally during the winter. The buds began to swell about December 18. Most of the bloom was shed by January 10 and not 1 per cent of this bloom set fruit.

The buds on two large seedling trees on the Roop place were beginning to push out on December 24, and one of these was selected to be sprayed every other day to test the efficacy of spraying to control the blossom-blight form of the disease. It was considered that this would be a thorough test, as the blighting of the blossoms is the normal thing with the winter bloom. Mr. Roop states that these trees have bloomed regularly in the winter for the past six years, but have never set fruit from this bloom. Spraying was begun on December 24 and continued every third day until January 16. At this time the fruit had set, and the spraying was continued every fourth day until February 3. At this time the young fruits had reached a diameter of one-fourth to three-eighths of an inch, and the next two sprayings were applied at 7-day intervals. Two more were applied at approximately 10-day intervals and the last on March 22 after a lapse of 14 days, when the fruit was about half grown. The dates on which spray was applied follow: December 24, 26, 28, 30; January 1, 3, 6, 8, 10, 13, 16, 20, 24, 28; February 3, 10, 17, 26; March 8, 22.

While the tree bloomed profusely, only a fair crop was set. By this is meant that the tree could have carried twice as much fruit without being unduly burdened. The blossoms on fully half of the panicles blighted, and all of those on the unsprayed tree blighted.

This experiment was carried a step farther in March by spraying a portion of a Totafari tree in the Subtropical Garden at Miami every day from March 17 to April 1; that is, while the bloom was pushing out and developing. This was evidently too much spraying, for, while no disease developed, no fruit was set and the young foliage was scorched.

It should also be noted that the fruit on the seedling tree on the Roop place received no spray after it was half grown, but it was clean and free from disease when harvested the middle of May, almost two months after the last spraying.

An experiment was conducted on the spring bloom about 3 miles northwest of Miami, on a place managed by Mr. C. O. Hickok. It included a block of 25 seedling trees which bloomed profusely between March 8 and 28. Spraying was begun when the panicles on most of them were about half grown, March 14. The flowers on six trees were beginning to open when the first spray was applied. No trace of disease was apparent on the inflorescence at that time. Seven trees were left without spray, as controls. The spraying dates were as follows: March 14, 20, 25; April 2.

Sprayed and unsprayed trees alike blighted. An occasional fruit was set, but the total number was negligible and the unsprayed trees had quite as much proportionately as the sprayed.

DISCUSSION OF THE SPRAYING EXPERIMENTS.

Mangos come into bloom very irregularly. On March 8, 1912, on the Flanders place most of the buds were just beginning to swell, but a number had reached a length of 4 or 5 inches. This habit of irregular blooming makes it difficult to select a proper time to begin spraying. Spraying before the buds begin to grow is of no value so far as protecting the inflorescence, and later the young fruit, is concerned. These must be kept covered with the fungicide while growing if fungus invasion is to be prevented. The difficulty of so protecting the inflorescence is at once apparent. Elongations of the panicles continue for a period ranging from 10 to 15 days. Those which were sprayed every third day were practically all disease free when the flowers began to open. This, however, required four sprayings in one case and six in the other. Those sprayed every fourth day showed but little more disease than those sprayed every third day, but those on which the spray was applied at 5 and 6 day intervals had traces of disease, showing that they were less perfectly protected.

The spraying of the inflorescence at least three times, beginning when the buds are just swelling and repeating every fourth day until the flowers open, will help to prevent the dropping of fruit caused by the disease on the peduncles and pedicels.

The blighting of the blossoms is by far the most serious form of this disease, as it does not lend itself to control by spraying. The inflorescence may be kept in a clean condition up to the time of blooming; but, when this takes place, immediately there are hundreds of points which are not covered by the fungicide and are open to infection. Observation has shown that infection takes place in this manner. A Totafari tree in the Subtropical Garden bloomed heavily in March, 1912. It was sprayed three times with Bordeaux mixture between the times when the buds began to swell and the flowers opened. The peduncles and pedicels showed no trace of disease when the flowers began to open. On March 26 the tree was in full bloom and there was every indication that a good crop of fruit would be set.



A SUNDERSHA MANGO TYPICALLY MARKED BY THE ANTHRACNOSE FUNGUS. MIAMI, FLA., JUNE, 1912. PHOTOGRAPHED BY J. M. SHULL.

(Natural size.)



FIG. 1.—THE END OF A MANGO BRANCH SHOWING A PERSISTENT, DISEASED PEDUNCLE OF THE JANUARY BLOOM, WITH A SECOND BLOOM APPEARING AROUND IT. MARCH, 1912.

(Considerably reduced.)



FIG. 2.—A PEDICEL FROM A MANGO PANICLE WHICH BLIGHTED BEFORE THE FLOWERS OPENED. MARCH, 1912.

(Natural size.)



FIG. 3.—YOUNG MULGOBA MANGO FRUITS WHICH SET ON DISEASED PEDICELS. APRIL, 1912.

(Natural size.)

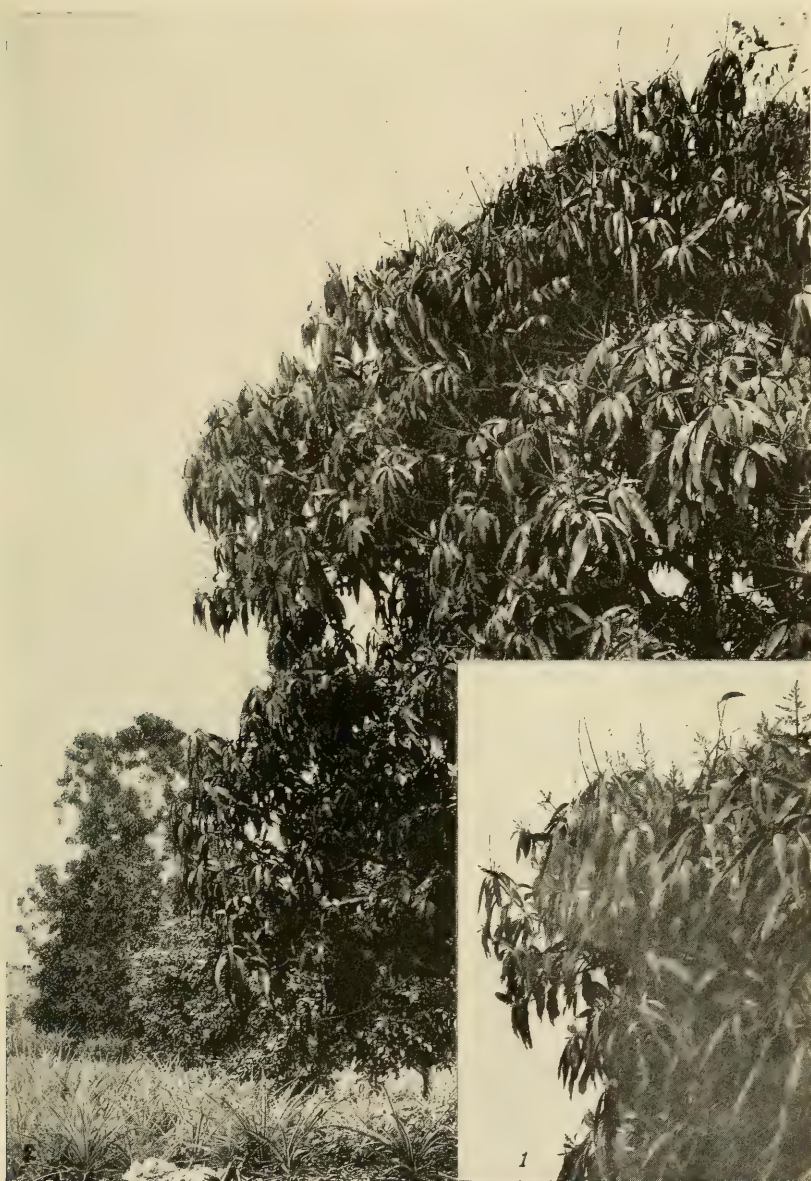


FIG. 1.—A SECTION OF THE TREE SHOWN IN FIGURE 2 OF THIS PLATE, SHOWING THE PERSISTENT, DISEASED PEDUNCLES OF THE JANUARY BLOOM, WITH THE MARCH BLOOM APPEARING AROUND THEM. MARCH 8, 1912. FIG. 2.—A LARGER VIEW OF THE SAME TREE SHOWN IN FIGURE 1, SHOWING THE BLIGHTED CONDITION OF THE SECOND BLOOM 18 DAYS LATER. MARCH 26, 1912.



FIG. 1.—A PORTION OF A SPRAYED MANGO PANICLE WHICH DOES NOT YET SHOW ANY SIGN OF DISEASE. MARCH, 1912. FIG. 2.—AN UNSPRAYED PANICLE ON WHICH THE FLOWERS HAVE BLIGHTED AND FALLEN OFF. MARCH, 1912.

On March 28 all the flowers were dead and dry, and most of them were still adhering to the pedicels. On April 5 the pedicels showed diseased spots as far as the flowers extended. No infection developed on the peduncles. Both the peduncles and pedicels were covered with Bordeaux mixture at this time. The spots on the pedicels developed beneath the mixture, indicating that infection had taken place through the blossoms. A number of these pedicels were placed in a moist chamber, and they all produced spores of the anthracnose fungus in abundance. These observations coincide entirely with those made on the sprayed seedling tree in the Roop experiment in the spring of 1912.

Very little infection occurred in 1913 before the blossoms opened, and this was undoubtedly due to the fact that the weather was quite dry during seven of the first eight days that the bloom was putting out.

Resistant varieties seem to be the only solution of the blossom-blight problem in localities that are subject to rainy weather at blooming time. The Mulgoba mango seems to possess this resistant quality in some degree. A single Mulgoba tree on the Roop farm bloomed at the same time as the seedling trees used in the experiment in the spring of 1912 and received the same spray treatment on the same dates, from the time the buds began to swell until the fruit was harvested. This tree was located most favorably for infection, in the midst of seedling trees which bloomed at the same time, but it set a good crop of fruit and carried it through to maturity. No fruit was set on the seedling trees, with the exception of the one that was sprayed.

On the Boggs farm, south of Miami, was found a collection of Mulgoba and seedling mangos intermixed in the planting. Most of these trees bloomed in March, 1912, and none of them were sprayed. The seedlings set no fruit, while the Mulgoba trees set a fair crop. The disease developed, however, quite seriously on the young fruits a week or ten days after they were formed. The peduncles and pedicels developed the disease also, so that none of the fruit was carried to maturity. Plate II, figure 3, shows the diseased condition of the pedicels after the fruit had set. Plate II, figure 2, shows a pedicel which blighted without setting fruit.

On the Flanders place a similar condition was observed. The flowers on the unsprayed blocks seemed to set fruit quite as well as those on the sprayed blocks, but the unsprayed fruit developed disease a week or ten days after it was formed, and, as the peduncles and pedicels were likewise diseased, practically none of it matured. There is some evidence to show that the *Sundersha* variety possesses the quality of resistance.

Briefly, then, it seems that the inflorescence can be kept in a disease-free condition by spraying often enough, and that after the

fruit is set it can be brought through to ripening free from fungous infection by spraying at certain intervals, but that spraying is of little or no value in controlling the blossom-blight form of the disease and that profitable sets of fruit can be expected only during seasons which are dry at blooming time, unless varieties which are resistant to the disease are developed and cultivated. Spraying every day prevented a set of fruit and spraying every other day did not save sufficient fruit to justify the expense involved.

There are not sufficient data to make definite and conclusive recommendations as to the frequency with which it will be necessary to spray to get the best results, but it seems probable that the panicles should be sprayed at least every fourth day between the times the buds begin to swell and the flowers begin to open and that after the fruit is set it should be kept covered with Bordeaux mixture during the first 8 to 10 weeks of its development. The fruits are most susceptible to infection just as they are setting. Consequently, it appears that it would be best to make three applications of Bordeaux mixture at weekly intervals, applying the first when about one-half to two-thirds of the blossoms have opened, and following these by a fourth application after a lapse of two weeks and a fifth three weeks later, making five sprayings for the fruit and two, or in some cases three, for the panicles.

INFLUENCE OF THE WEATHER ON POLLINATION.

It has been tentatively suggested by Fawcett¹ and by Collins¹ that the blighting of the blossoms, which is so uniformly observed throughout the Tropics whenever the mango is subject to moist, showery weather at blooming time, may be due to lack of pollination.

It is probable that such conditions interfere with pollination to some extent, but the evidence at hand points strongly to the fact that in Florida, at any rate, the anthracnose fungus is chiefly responsible for this phenomenon. Repeated attempts have been made to germinate the pollen, but without success. The fact that the mango fruits heavily in dry localities indicates that its shy bearing in Florida is due to external conditions rather than to any inherent defect in the plant.

An exact count was made of the number and types of flowers borne on 10 panicles of a Mulgoba, 10 of a Totafari, and 5 of a seedling mango tree. They were made by going over the flower clusters every day and picking off with a pair of forceps the flowers that had opened, the kind and number being recorded. The mango bears two types of flowers, staminate and perfect, and only one stamen is found in each flower.

The 10 Mulgoba panicles bore a total of 7,038 flowers, of which 4,119 were staminate and 2,919 perfect. The 10 Totafari panicles

¹ Op. cit.

bore 9,218 flowers, of which 8,407 were staminate and 811 perfect, and the five seedling panicles bore 2,429 flowers, of which 1,022 were staminate and 1,407 perfect.

The flowers are opening continuously throughout the day and night, and after opening retain their fresh appearance for about two days. The staminate flowers wither and drop off the third or fourth day, while the ovaries of the perfect flowers generally begin to take on a dark-green color on the third day.

A peculiar condition is observed when panicles bearing freshly opened flowers are removed from the tree. Within 15 to 30 minutes the pistil and stamen of each perfect flower curve toward each other and frequently meet, and in some cases wrap themselves together.



FIG. 1.—Complete mango flowers, much enlarged: *A*, A freshly opened flower; *B* and *C*, flowers which have been removed from the tree for 30 minutes, showing the flexing of the stamen and pistil.

This condition has never been observed on the tree and is not thought to have any bearing on the fertilizing processes of the flower. Figure 1, *A*, shows a freshly opened flower, and figure 1, *B* and *C*, shows the flexing of the stamen and pistil after the flower has been removed from the tree.

RELATIONS OF WEATHER CONDITIONS TO THE DISEASE.

That there is a very definite relation between weather conditions and the productiveness of the mango has been observed by various writers.

Fawcett and Harris,¹ writing of the mango in Jamaica, have the following to say on this point:

Although the mango grows freely everywhere, it is not a fruitful tree in every district; in the southern plains and the low, dry limestone hills it produces enormous crops year after year, and very often two crops a year, the main crop from May to August, and the second crop later in the year. * * * In humid districts and along the northern coast the tree is not at all fruitful, except in very dry years, and in the wet districts like Castleton it rarely fruits.

¹ Fawcett, William, and Harris, W. The mango. Bulletin, Botanical Department, Jamaica, n. s., v. 8, pt. 11-12, p. 161-177, 1901.

Collins,¹ discussing the mango in Porto Rico, says:

As to climate, it is much more exacting, and the fact that the tree may thrive well in a given locality and yet fail to produce fruit should be kept always in mind. It may be considered as proven that the mango will be prolific only in regions subject to a considerable dry season. On the moist north side of Porto Rico the trees grow luxuriantly, but they are not nearly so prolific nor is the fruit of such good quality as on the dry south side, and in the very dry region about Yauco and at Cabo Rojo the fruit seems at its best. * * * In Guatemala and Mexico the mango was found at its best only in regions where severe dry seasons prevailed. This position is amply supported by reports of the mango in other localities. * * * Rains at the time of flowering seem to be especially injurious.

Higgins² has observed the same condition in Hawaii and writes as follows:

In connection with what has just been said, it will be recalled that the early months of 1904 were marked by heavy rainfall and almost continuous cloudy, wet weather, while the corresponding months in 1905 were exceptionally dry. This unquestionably had much to do with the large crop of mangos produced during the season just passed.

Unfortunately, no bloom records for Florida prior to 1912 are available, but the conditions that prevailed during that season as regards weather and the failure to set fruit are quite in accord with the observations just presented. The seedling mangos in the region around Miami bloomed during the first two weeks of January, 1912. By referring to the Monthly Meteorological Summary of the United States Weather Bureau at Miami for this month, it is seen that of the first 15 days 9 were cloudy, 3 partly cloudy, and 3 clear. Further, out of these 15 days rain fell on 10, the precipitation ranging from 0.01 to 0.66 of an inch, the total precipitation being 1.94 inches. As mentioned previously, practically all of the seedling trees bloomed heavily, but none set fruit.

Most of the second crop of bloom developed during the first 20 days of March, and while some fruit was set from this bloom it was exceedingly light as compared with the amount of bloom. The Monthly Meteorological Summary for the first 20 days of this month shows 10 days cloudy, 9 partly cloudy, and 1 clear. Rain fell on 9 of the 20 days, the precipitation varying from a trace to 1.44 inches, with a total precipitation of 3.17 inches.

The situation was quite as bad during the spring of 1913. The blooming period extended from March 7 to 26 and rain fell on 8 of the 19 days. The black areas in figure 2 show the distribution of the days on which rain fell during the blooming periods of 1912 and of 1913.

It is seen from the foregoing that the suitability of any region for the successful production of mangos is inextricably connected with

¹ Collins, G. N. The mango in Porto Rico. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 28, p. 13, 1903.

² Op. cit.

the condition of the weather at blooming time. Given clear dry weather, a good crop of fruit may be expected. Given, on the other hand, rainy weather at blooming time and a failure is practically certain. The only way of telling with certainty that a particular region is suitable for the profitable production of mangos is to have a combined crop and weather record over a sufficiently long term of years to give a fair average. The precipitation records alone are somewhat unreliable. However, the main limiting factor in the successful production of this fruit on the southeast coast of Florida is the anthracnose fungus, which is induced by rainy weather, so a study of the precipitation records for this locality, together with such crop records as are available, is of considerable value. Figures 3 and 4 show the number of rainy days during the months of February and March, respectively, for the period for which a record exists, 1898 to 1913, inclusive, and figure 4 also shows a crop curve for the past four years. The lack of fruit in 1911 was due to the fact that the trees were defoliated the preceding fall by a West Indian hurricane and did not bloom. The curve for the years 1910, 1912, and 1913 shows the relation between the precipitation at blooming time and the crop. There are no bloom records prior to 1912, so

to some extent this makes the data unreliable. For example, there might be only five days of rain in a certain month, and it might fall at such a time as to cause no damage; or, on the other hand, there might be five consecutive days of rain at the time that the flowers were opening, which would probably be sufficient to cause the loss of the crop. It would seem, however, that such a combination of circumstances might be expected to be a rather rare occurrence and that an opinion as to the suitability of this region might be predicated on such precipitation records as these with a reasonable degree of certainty.

The records for Miami which are given in figures 3 and 4 cover a period of 16 years and show the mean number of rainy days for February to be 2.81 and for March 4.56. The number of seasons below normal for this term of years for February is 8 and for March 11. It is clearly seen here that the seasons of 1912 and 1913 have been decidedly abnormal as regards precipitation.

Wester's¹ experiments, which have been previously referred to, were conducted at Miami during the springs of 1906 and 1907. It will be seen by referring to figures 3 and 4 that these two seasons were comparatively dry, and this undoubtedly accounts for the

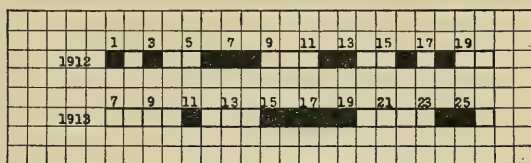


FIG. 2.—Diagram showing the blooming periods, March 1-20, 1912, and March 7-26, 1913. The dark areas show rainy days.

¹ Op. cit.

success which he reports with the use of Bordeaux mixture. He fails to present his experimental data, however, and his statements in this and a subsequent publication¹ in regard to this disease are so general that they are of practically no value to the grower.

The fact that the mango frequently blooms during the latter part of December and the first part of January has been previously mentioned. It is the rare exception when any fruit is set from this bloom. Aside from rainy weather at the time of blooming, the extremely heavy dews, which are an almost nightly occurrence during the winter months, are, it would seem, largely responsible for this. The dew point is generally reached shortly after sundown, and by 8 o'clock p. m. plants and other outdoor objects are usually dripping with water. With such ideal conditions for infection the uniform blighting of the winter bloom is not to be wondered at.

From a consideration of the data presented, it appears that, while total failures may be expected to occur occasionally, more often the weather conditions will be such as favor good settings of fruit on the spring bloom and that this fruit may be brought through to maturity in a clean and disease-free condition by a moderate number of sprayings with Bordeaux mixture.

SUMMARY.

The production of mangos in Florida is seriously interfered with in certain seasons by a fungus which attacks the flower clusters, fruits, leaves, and young shoots.

Infection experiments by the writer and others have shown that *Colletotrichum gloeosporioides* Penz. is the cause of the disease.

The blossom-blight form of the disease is by far the most serious. The amount of damage done by this fungus depends on weather conditions, moist, showery weather being ideal for its ravages.

Spraying with Bordeaux mixture is of little or no value in preventing the blighting of the blossoms during seasons which are rainy at

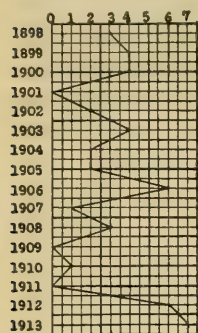


FIG. 3.—Diagram showing the number of days at Miami, Fla., in February, 1898 to 1913, inclusive, with 0.01 inch or more of rainfall. The mean for this period is 2.81 days.

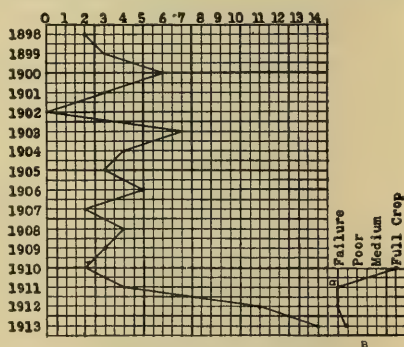


FIG. 4.—A, Diagram showing the number of days at Miami, Fla., in March, 1898 to 1913, inclusive, with 0.01 inch or more of rainfall. The mean for this period is 4.56 days. B, Crop curve. (a) The failure of 1911 was due to the defoliation of the trees the preceding fall by a West Indian hurricane, the trees not blooming that season.

¹ Wester, P. J. The mango. Philippine Islands, Bureau of Agriculture, Bulletin 18, 60 p., 9 pl., 1911.

blooming time, though spraying has served to keep the panicles and fruits free from infection.

It appears that while total failures may sometimes occur, more often the weather conditions will be such as to favor good settings of fruit.

It is probably never so dry but that spraying will have to be resorted to in order to keep the fruits free from disease after they have set, and no amount of fertilization or soil medication will take its place.

The production of good crops of mangos in Florida and throughout tropical and subtropical zones generally is very definitely related to the weather conditions at blooming time. Large crops can not be expected when the weather at this time is moist and showery. This may be due to some extent to imperfect pollination, but the trouble is chiefly caused in Florida by the anthracnose fungus (*Colletotrichum gloeosporioides*).

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

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Contribution from the Office of Public Roads, Logan Waller Page, Director.

December 31, 1913.

OBJECT-LESSON AND EXPERIMENTAL ROADS, AND BRIDGE CONSTRUCTION, 1912-13.

INTRODUCTION.

The United States Office of Public Roads is empowered by a provision of the agricultural act to expend a portion of its appropriation "for investigations of the best methods of road making and the best kinds of road-making materials, and for furnishing expert advice on road building and maintenance."¹ The terms of this clause have been interpreted to include the construction of short stretches of various kinds of roads in different communities for the purpose of serving as object lessons to the officials having charge of the roads and to the citizens who use them. The desire of the office has been to demonstrate in a practical way the need for good roads and at the same time show to the community the proper method of economical road construction.

The work of the office is limited to furnishing the services of one or more expert engineers to make the surveys, estimates, and specifications for the road, to supervise its construction, and to give practical advice to the local authorities who must furnish all machinery, materials, and labor. The community where the road is to be built is first required, through the officials having jurisdiction over the proposed road, to make application to this office on a prescribed form.

As an illustration of the growth of the office the following table is given. It shows the area in square yards of each type of road constructed during the fiscal years 1905 to 1913, inclusive:

Area, in square yards, of object-lesson roads constructed during 1905-1913, inclusive.

Material.	1905	1906	1907	1908	1909	1910	1911	1912	1913 ²
Brick.....						526			2,055
Concrete.....						1,004			3,218
Oil-cement concrete.....							1,917		1,744
Bituminous concrete.....									5,500
Bituminous-surfaced concrete.....									4,178
Bituminous macadam.....						45,832	41,551	34,453	.....

¹ Agricultural act, 1914, Public No. 430, 62d Cong., 3d sess. Approved March 4, 1913.

² Includes experimental roads.

Area, in square yards, of object-lesson roads constructed, etc.—Continued.

Material.	1905	1906	1907	1908	1909	1910	1911	1912	1913 ¹
Surface treatment.....									10,831
Macadam.....	44,944	51,246	76,376	72,587	96,107	50,333	11,330	14,806	56,253
Asphalt slag.....							578		
Oil-asphalt gravel.....							900		
Oil gravel.....						4,819	9,774		
Oil-coraline.....									2,804
Gravel macadam.....									2,607
Gravel.....	8,804	4,197	11,722	4,608	65,793	71,376	59,942	13,057	63,730
Slag.....						4,610			
Sand clay.....	19,178	19,443	85,571	42,634	205,032	177,960	218,177	103,876	128,496
Sand gumbo.....									5,337
Burnt clay.....	400			3,392	2,041				
Shell.....	5,877	933		14,020	1,630				40,646
Earth.....		12,132	27,042	85,967	319,456	651,109	140,933	556,663	160,932
Total.....	79,203	87,951	200,711	223,208	690,059	1,007,569	485,102	722,855	488,331

¹ Includes experimental roads.

During the fiscal year 1912-13 the Office of Public Roads, under the general direction of the chief engineer, Vernon M. Peirce, and the immediate control of the highway engineer in charge, B. F. Heidel, supervised the construction of object-lesson roads as follows: One bituminous-concrete, 1 bituminous-macadam, 7 macadam, 4 gravel, 1 gravel-macadam, 1 brick-cinder, 14 sand-clay, 1 sand-gumbo, 3 shell, and 9 earth. Three other roads begun during the past fiscal year were not completed, and the description of the work on them will be reserved for the next annual report. Exclusive of the assistance afforded by the office in the form of the salaries and expenses of its engineers, the object-lesson roads described below cost the various communities in which they were located \$94,323.68.

This bulletin includes, in addition to the object-lesson work of the office, a brief account of the experimental work for the past fiscal year, and reports of the bridge work and inspection of object-lesson roads as conducted under the immediate supervision of Charles H. Moorefield, highway engineer, and E. W. James, chief inspector, who report to the chief engineer.

BITUMINOUS-CONCRETE ROAD.

CHEVY CHASE CLUB, MD.—A driveway through the grounds of the Chevy Chase Club, approximately 1,395 feet long, was graded and surfaced with bituminous concrete on a broken-stone base between May 7, 1913, and June 28, 1913. Three days were lost on account of unfavorable weather and 12½ days for other reasons. The road is 10 feet wide for a length of 150 feet, 15 feet wide for 945 feet, and from 20 to 23 feet wide for 300 feet, making a total area of 2,807 square yards. Of this area 2,602 square yards were surfaced with bituminous concrete and 205 square yards with Portland cement concrete. The maximum cut was 1.5 feet, the maximum fill 0.5 foot, and the maximum grade remained 7 per cent. The adjacent land is rolling and the soil is mica-clay. The drainage structures had all been constructed before this work was begun and were paid for separately.

Four hundred and ninety tons of crushed limestone, all passing a 3-inch mesh screen and retained on a 1-inch mesh screen, were used in constructing the broken-stone base. This material was spread upon the prepared subgrade, so that the compacted depth was $4\frac{1}{2}$ inches. Sixty tons of sand were flushed into the voids in the broken-stone base by sprinkling and rolling. The bituminous concrete was prepared according to the Topeka specifications at the plant of a Washington contractor, and hauled in tarpaulin-covered automobile trucks a distance of approximately 6 miles to the work. The material arrived on the ground at a temperature of approximately 380° F., and was immediately spread upon the completed broken-stone base. It was then rolled, first with a 3-ton tandem roller, and finally with an 8-ton tandem roller, to a compacted thickness of $1\frac{1}{2}$ inches. Pieces of 2 by 4 inch lumber, laid flat at the sides of the road, served as forms to retain the bituminous material during the process of laying and rolling. These were removed, however, upon completion of the rolling and replaced with a sodded earth shoulder. A seal coat of pea gravel and a native asphalt emulsion was finally applied to the surface of the concrete and lightly rolled with a 3-ton tandem roller. The emulsion was applied at the rate of approximately one-tenth gallon per square yard and the gravel at the rate of 1 cubic yard to every 200 square yards of surface.

Automobile parkways having a total area of 205 square yards were constructed of Portland cement concrete mixed in the proportions of 1 part of cement, 2 parts of sand, and 4 parts of crushed limestone. Second-hand 3 by 6 inch lumber was set on edge for forms and the concrete was laid and struck off to a depth of 5 inches, after which the surface was floated with a wooden float.

Seventy linear feet of concrete gutter crossings, having a width of $4\frac{1}{2}$ feet and a total thickness of 6 inches, were constructed. The concrete for the gutter was mixed in the same proportion as that for the parkway, except that the top one-half inch consisted of 1:2 mortar. The total cost of the road, exclusive of drainage structures, was \$3,461.56, which is at the rate of \$1.211 per square yard.

The principal items of cost were as follows: Grading and preparing the subgrade, 2,807 square yards at \$0.174 per square yard, \$490.12; total cost of stone for the base f. o. b. siding, 490 tons at \$1.10 per ton, \$539; loading and hauling the stone (length of haul $1\frac{1}{2}$ miles), 490 tons at \$0.623 per ton, \$305.30; sand filler delivered on the work, 60 tons at \$1.557 per ton, \$93.40; spreading the stone, 490 tons at \$0.161 per ton, \$79.01; spreading the sand filler, 60 tons at \$0.106 per ton, \$6.36; rolling the broken-stone base, 2,602 square yards at \$0.028 per square yard, \$59.27; bituminous concrete at the plant, 2,602 square yards at \$0.40 per square yard, \$1,040.80; hauling the bituminous concrete from the plant to the road, 2,602 square yards at \$0.032 per square yard, \$82.50; native asphalt emulsion on the road, 2,602 square yards at \$0.012 per square yard, \$32.50; gravel for the seal coat, 2,602 square yards at \$0.011 per square yard, \$28; forms for the bituminous concrete, \$5; setting the forms for the bituminous concrete, \$21.15; spreading the bituminous concrete, 2,602 square yards at \$0.039 per square yard, \$101.75; rolling the bituminous concrete, 2,602 square yards at \$0.024 per square yard, \$62.60; cement concrete automobile parkways, exclusive of preparing the subgrade, 205 square yards at \$1.237 per square yard, \$278.45; cement concrete gutters, exclusive of the subgrade, 70 linear feet at \$0.868 per foot, \$60.75; miscellaneous expenses, \$58.14; and general expenses, \$142.35. The above costs are based on labor at \$1.60 and teams at \$4.50 for an eight-hour day.

BITUMINOUS-MACADAM ROAD.

SILVER SPRINGS, MD.—The seal coat was renewed on the bituminous-macadam drive extending from Silver Springs station to the Blair estate, the construction of which was supervised by the Office of Public Roads during the year 1912 and described in its annual report for that year. Work was begun on June 27, 1913, and completed on July 1, 1913. The road is 2,776 feet in length and 12½ feet wide, making a total area of 3,856 square yards. The road surface was first thoroughly cleaned with stiff brooms, after which a total of 1,075 gallons of a light water-gas tar preparation was applied to the road directly from the drums at the rate of approximately 28 gallons per square yard. This material was then distributed by means of hand brooms so as to form a uniform coating over the entire surface. Sixty-six tons of pea gravel were spread over the bituminous material at the rate of approximately 0.0133 cubic yard per square yard. The surface was then lightly rolled with a 10-ton macadam roller.

Several water-bound macadam patches, aggregating 100 square yards in area, were made. Seven and one-fourth cubic yards of crushed limestone and 4½ cubic yards of limestone screenings were used for this purpose.

The entire cost of renewing the seal coat was \$283.78, while the patches cost \$49.07. The cost of the road per square yard for the seal coat was \$0.0736. The principal items of cost were as follows: Bituminous material, delivered at the station, 1,075 gallons, at \$0.095 per gallon, \$102.13; loading and hauling the bituminous material to the road, \$12.55; pea gravel, delivered at the station, 66 tons, at \$1.20 per ton, \$79.20; loading and hauling the gravel to the road, \$7.05; sweeping the road surface, \$8.33; applying the bitumen, \$23.83; spreading the gravel, \$11.50; rolling, \$23.65; limestone for patching the macadam, 11½ cubic yards, at \$2 per cubic yard, \$23; labor for patching the macadam, \$25.57; coal for the roller, \$3.50; and general expenses, \$12.50. The above costs are based on labor at \$1.60 and teams at \$4.75 per nine-hour day.

MACADAM ROADS.

BLACK ROCK, ARK.—Work was begun on a macadam road extending from Black Rock westward toward Smithville on September 25, 1912, and discontinued for lack of funds on October 26, 1912, with the loss of 1½ days on account of bad weather.

The land adjacent to the road is hilly, and the natural soil is clay. The road was graded 30 feet wide in cuts and 20 feet wide in fills for 2,600 feet, making a graded area of 7,500 square yards. The maximum cut was 3½ feet, the maximum fill 3 feet, and the total amount of excavation 2,620 cubic yards. Earth was loosened with plows, hauled with drag and wheel scrapers, and spread by hand and with a road grader. The average haul for excavation was 75 feet and the maximum, 300 feet.

A surface of macadam was laid for 1,300 feet, 12 feet wide, making 1,733 square yards. For 660 feet the macadam was applied in two courses, each 5 inches thick at the center and 4 inches at the sides before compacting, and throughout the remaining 640 feet it was applied in one course. In both instances the material was compacted 8 inches at the center and 6 inches at the sides. The material used for surfacing was a hard magnesian limestone with good binding qualities. The run of the crusher was used for both the first and second courses; and the maximum size in the first course was 4 inches and in the second course 2½ inches. "Chats," or the tailings from a zinc mine, were used as a binder in an amount just sufficient to bind the surface properly. This material was similar to that used for surfacing. It ranged in size from one-

half inch to dust. The stone was obtained under contract from a local quarry, where a crusher having an average capacity of 50 cubic yards per 10-hour day was already located. The average haul of water for the crusher was three-fourths mile. Stone was brought to the crusher in wheelbarrows, crushed, stored in bins, loaded from the bins into farm wagons which were equipped with dump boards, and hauled to the road for an average distance of 3,500 feet, where it was spread by hand with iron hooks. A 6-ton horse roller was tried for compacting the surface, but was found to be impracticable. The hoofs of the mules loosened the surface as rapidly as it was compacted. No sprinkler wagon was available, and, as the road was constructed during a comparatively dry season, it is probable that the surface could not have been properly bonded, even with a more suitable roller. It was, therefore, left in a loose condition. Before leaving the work, however, the representative of the office instructed the local authorities regarding the proper manner of bonding the road when the weather became suitable.

Drainage structures were constructed as follows: At station 2+50 the existing concrete abutments of a culvert of 13-foot span were extended and the wooden floor was renewed; at station 10+85 concrete wing walls were added to an existing culvert of 4-foot span, and a new wooden floor was constructed; at station 15+55 a new 10-foot span reinforced concrete culvert was constructed; and corrugated iron culverts, 12 inches in diameter and 18 feet long, were placed under approaches to private entrances at stations 4+00, 6+60, 13+25, and 14+15.

The concrete used in the abutments, wing walls, and footings was made of cement and unscreened gravel in the proportion 1:6. In reinforced work cement, sand and screened gravel were used in the proportion 1:2:4, and the concrete used in the parapets was made of cement, sand, and gravel in the proportion 1:2:3.

The equipment consisted of one 6-ton horse roller, two steel road drags, one road grader, and hand tools. Labor cost \$1.50 per day of 10 hours, and teams cost \$2.50 and \$3.

The total cost of the road was \$2,153.45, which is at the rate of \$1.01 per square yard. The principal items of cost were as follows: Excavation, at \$0.203 per cubic yard, \$532.25; shaping the subgrade, at \$0.0234 per square yard, \$40.50; crushed stone, at \$0.875 per cubic yard, \$405.15; hauling stone from the crusher to the road, at \$0.343 per cubic yard, \$178.50; spreading stone, at \$0.116 per cubic yard, \$60; rolling, at \$0.04 per square yard, \$70; trimming the shoulders and ditches, \$46.25; culverts, \$1,218.45; and general expenses, \$7.50.

LOUISVILLE, KY.—On April 4, 1913, excavation was started on an object-lesson macadam road at Louisville, Ky., and was continued until April 12. The weather conditions were so unfavorable during this period, however, that very little could be accomplished. About \$175 was expended, but on account of the continual rain the results of the work done were practically negligible. On April 12 the work was discontinued, but it is hoped that it may be resumed at some more favorable season and the project eventually completed.

JERUSALEM, N. C.—Surfacing was started on a road leading from Jerusalem southeast toward South Yadkin River on October 15, 1912, and completed on December 2, 1912. The road had been graded before the arrival of the representative of the Office of Public Roads, and no data concerning the cost of grading could be obtained. The land adjacent to the road is rolling, and the soil is sandy loam from station 0+00 to station 13+00 and red clay from station 13+00 to station 20+00. The macadam surface is 2,210 feet long and 12 feet wide, making a total area of 2,950 square yards. The stone consisted of coarse-grained

light granite for the foundation course and trap or field stone for the wearing surface. The compacted depth of the foundation course was $3\frac{3}{4}$ inches, and of the top course, including the screenings, $2\frac{1}{4}$ inches. Surfacing material to the amount of 655 cubic yards was used, and of this 364 cubic yards was purchased.

Concrete gutters 1 foot wide, 3 inches thick, and dished from 1 inch to 2 inches, were constructed on each side of the road throughout its length. Cross drains 14 feet long, of bell-joint pipe, were constructed at stations 3+00, 5+50, 10+75, 13+00, and 18+50. The diameter of the first four drains was 4 inches and of the last 6 inches. The ditches for the cross drains in each case were filled with broken stone. Underdrains of 6-inch bell-joint pipe 12 feet, 33 feet, 40 feet, and 16 feet long were constructed at stations 3+00, 5+50, 10+75, and 13+00, respectively. Concrete drop inlets 10 inches square and 2 feet deep, having 3-inch walls, were provided for these drains. Three hundred and seventy-four sacks of cement were used in constructing the gutters and drop inlets.

The equipment consisted of a crusher having an average capacity of 50 cubic yards per 10-hour day, a 10-ton roller, a sprinkling cart, and slat-bottom road wagons. The crusher and roller were both borrowed, and the only cost in connection with their use was the operating and maintenance expenses. The average haul from quarry to crusher was one-half mile and from crusher to road 500 feet. The water for the crusher, roller, and sprinkler was pumped.

The total cost of surfacing the road was \$2,073.07, and the rate per square yard \$0.703. Labor cost \$1.40 per day, teams \$3 per day, and fuel \$6 per ton. The principal items of cost were: Materials for concrete gutters and drop inlets, \$192.30; labor for these gutters and inlets, \$120.05; drainpipe, \$17.16; labor for the drainpipe, \$7.07; surfacing material, \$273; quarrying, \$243.54; hauling to the crusher, \$251.52; crushing, \$136.38; hauling from the crusher to the road, \$153.45; spreading, \$140.17; sprinkling, \$13.50; rolling, \$13.13; hire of the sprinkler, \$25; explosives, \$99.50; crusher repairs, \$25; drill steel, \$28.40; sharpening the drill steel, \$16.40; fuel, \$62.10; lubricating oil, \$12.50; loosening old macadam, \$16.80; screening, \$2.80; clearing, \$25.90; and general expenses, \$197.40.

MONROE, N. C.—A macadam road leading southeast from Monroe toward Wingate, known as the Lee Mill Road, was started on October 12, 1912, and completed on November 22, 1912, and during this time $3\frac{1}{2}$ days were lost on account of unfavorable weather. This road had been graded before the arrival of the office representative, and no data relative to the cost of grading were available. The grade varies from a maximum of 3 per cent to level. The adjacent land varies from rolling to hilly, and the soil is red clay and clay shale. Local sandstone was used for surfacing. This stone possesses good wearing qualities, but poor binding qualities, making it a good material for the foundation course, but not well suited for the top course.

The total length surfaced was 2,516 feet and the width 10 feet, giving a surfaced area of 2,789 square yards. The stone was laid in three courses—the bottom course consisting of stone varying in size from $1\frac{1}{2}$ inches to 4 inches, the second course from 1 inch to $1\frac{1}{4}$ inches, and the top course from dust to 1 inch. The total compacted depth of the surface was from $7\frac{1}{2}$ inches to 9 inches. The crown of the finished roadway was three-fourths inch to 1 foot. Stone to the amount of 1,133 cubic yards was crushed, but only 997 cubic yards was used. The stone was hauled from the quarry to the crusher for an average distance of 175 feet in wheelbarrows, and from the crusher to the road for an average distance of 2,000 feet in slat-bottom wagons with a capacity of approximately one cubic yard. The stone was loaded directly from the bins into the wagons. Water for the crusher engine was carried 200 feet by hand, and

hauled 300 feet for the roller. Four tons of fuel was used at the crusher and $5\frac{1}{2}$ tons by the roller.

The equipment consisted of a stone crusher having 73 cubic yards' capacity per 9-hour day, an engine, a 10-ton roller, slat-bottom wagons, and hand tools. Convict labor and teams owned by the county were used. The cost to the county per day per convict and per mule was \$0.45. The total cost of the road was \$647.15, making a rate of \$0.232 per square yard.

The principal items of cost were: Preparing the subgrade, \$22.95; quarrying, \$117.45; hauling to the crusher, \$66.60; crushing, \$50.40; hauling from the crusher to the road, \$112.94; spreading the stone, \$22.95; sprinkling, \$8.11; rolling, \$68.95; stacking and loading screenings, \$31.05; shaping shoulders, \$11.70; loss of time due to bad weather, \$57.35; and incidental expenses, \$76.70.

NORTHWILKESBORO, N. C.—Work was begun on a macadam road leading from Northwilkeshoro toward Wilkesboro on October 2, 1912, and was discontinued on December 21, 1912. Thirteen and one-half days were lost on account of bad weather. A section of road 800 feet in length was entirely completed and an additional length of 494 feet was partially completed. The section completed follows the Yadkin River, and the entire road is subject to overflow at flood seasons. To remedy this condition the grade of the road was raised and the macadam was laid on a Telford base.

The natural soil is clay and sil and the adjacent land is level. There was no cut, and the maximum fill was 3.9 feet and the average fill 2.1 feet. The maximum grade of 5.85 per cent was reduced to 2.5 per cent.

A total length of 1,294 feet was graded 30 feet wide. All the material for the embankment was taken from pits located at an average distance of three-eighths mile from the road and in no case more than one-half mile. It was loosened with a plow, loaded with shovels on slat-bottom wagons, and spread by hand.

A subgrade 16 feet wide was prepared for a distance of 1,294 feet and a Telford base 12 inches thick was laid upon it for the same distance. A macadam surface was laid upon this base to the same width for a distance of 800 feet. The surface was laid in two courses, each 3 inches thick compacted, and each course was bonded with screenings. The stone used on the bottom course consisted of pieces from $1\frac{1}{2}$ to 3 inches in size, and the stone used in the second course ranged from one-half inch to $1\frac{1}{2}$ inches. The screenings consisted of material ranging from dust to particles one-half inch in size.

The Telford base and the macadam surface were both made from mica gneiss obtained from the same quarry. This material possesses excellent binding and wearing qualities. It was quarried at an average distance of $1\frac{1}{2}$ miles from the road, crushed at the quarry, loaded into dump wagons by means of a chute from the bins, and hauled to the road, where it was spread with forks.

The following drainage structures were constructed: One reinforced concrete culvert 2 by 4 feet by 29 feet long; one reinforced concrete culvert 2 by 6 feet by 30 feet long; one reinforced concrete culvert 2 by 6 feet by 28.5 feet long; and one wooden-box culvert 2 by 3 feet at an intersecting road.

The equipment consisted of one stone crusher with a capacity of 25 cubic yards per day, elevator, bins, one 10-ton roller, six $1\frac{1}{2}$ cubic yard dump wagons, slat-bottom wagons, one turn plow, and hand tools.

The labor cost for men was \$0.12 $\frac{1}{2}$, \$0.13 $\frac{1}{2}$, and \$0.15 per hour, and double teams cost \$0.30 per hour. The working day was 10 hours long.

The total cost of the road was \$3,293.29, which is at the rate of \$1.8875 per square yard. The principal items of cost were as follows: Excavation and embankment, 979 cubic yards, at \$0.40 per cubic yard, \$391.60; clearing and grubbing, 2,300.4 square yards, at \$0.0017 per square yard, \$4; shaping the sub-

grade, 2,300.4 square yards, at \$0.06 per square yard, \$139.58; Telford foundation, 2,300.4 square yards, at \$0.489 per square yard, \$1,124.01; quarrying and crushing the surfacing materials, 380 cubic yards, at \$1.525 per cubic yard, \$579.49; hauling the surfacing materials, 380 cubic yards, at \$0.645 per cubic yard, \$245.30; spreading the surfacing materials, 380 cubic yards, at \$0.108 per cubic yard, \$40.93; sprinkling and rolling, 1,422.2 square yards, at \$0.15, \$213.63; reinforced concrete drainage structures, \$473; and general expenses, \$40.63. The above costs do not include any charge for the use of the stone crusher, elevator, and bins.

JONESVILLE, VA.—Between May 1 and October 17, 1912, a macadam road was built under the direction of the office at Jonesville, Va., and during this time 37 days were lost on account of bad weather and 5 days from other causes. The adjacent land is hilly and the natural soil is clay and gravel. The road was graded to a width of 20 feet for 8,200 feet, with the exception of a short section which was constructed 24 feet wide. For 2,200 feet the road was located on the side of a hill, and in this section 50 per cent of the excavation was solid rock. The total area graded was 21,860 square yards, and the maximum grade was reduced from 17 to 9 per cent. The total volume of earth and rock moved was 7,590 cubic yards and the maximum haul 800 feet. A macadam surface 6,800 feet in length was constructed upon a part of the graded section, 10 feet wide for a length of 4,500 feet, 12 feet wide for 1,800 feet, and 24 feet wide for the remaining 500 feet. The total area surfaced was 8,735 square yards. The surfacing material—a limestone of good binding but only fair wearing qualities—was obtained from a quarry five-eighths mile from the road. It was crushed at the quarry in a crusher having 50 cubic yards' capacity per 10-hour day, and after being hauled to the road in flat-bottom wagons of 1½ cubic yards' capacity was spread in three courses with forks and shovels. The first or foundation course, 7 inches in thickness before compacting, consisted of pieces varying from 2 to 3 inches in size; the second course, 3 inches thick, consisted of pieces from one-half inch to 2 inches in size; and the third or binder course, applied to a depth of approximately 1 inch, consisted of pieces varying in size from 1 inch to dust. Each course was compacted with a 10-ton roller, and was bonded in the usual manner with a sprinkler wagon and roller.

Culverts were constructed of corrugated-iron pipe as follows: At stations 10, 14, and 20, 12 inches in diameter and 22 feet in length; at station 17, 12 inches in diameter and 24 feet in length; at station 20, 15 inches in diameter and 24 feet in length; at stations 28 and 82, 24 inches in diameter and 40 and 26 feet in length, respectively; and at stations 43 and 52, 30 inches in diameter and 26 and 24 feet in length, respectively. End walls of rough stone were constructed at all culverts.

The equipment consisted of a 10-ton roller, a rock crusher, 5 wheel scrapers, 1 turn plow, 1 roofer plow, 2 dump carts, 1 steam drill, and hand tools. Labor cost \$1.50 and teams \$3.50 per day. The other principal items of cost were as follows: Excavation, at \$0.36 per cubic yard, \$2,726.95; shaping the subgrade, at \$0.024 per square yard, \$206.10; quarrying and crushing the stone, at \$0.93 per cubic yard, \$3,142.47; hauling the stone, at \$0.166 per cubic yard, \$506.30; spreading the stone, at \$0.07 per cubic yard, \$228.90; sprinkling, at \$0.0075 per square yard, \$60.85; rolling, at \$0.02 per square yard, \$183.70; trimming the shoulders, \$31.30; lowering the water pipes and raising the walks, \$48; culverts, \$261.56; supervision and general expenses, \$382.20; making the total cost of the road \$7,778.33. This is at the rate of \$0.837 per square yard.

NORTON, VA.—The work of macadamizing the Wise-Norton road was begun on August 1, 1912, and discontinued on December 15, 1912, after 3,360 linear feet or 4,340 square yards had been surfaced. The work was done by contract, and

the grading and culvert work had been finished before the macadamizing was started. Twenty-four days were lost owing to bad weather and $27\frac{1}{2}$ days from other causes. The land adjacent to the road is hilly and the soil is yellow clay. The maximum grade is 6 per cent and the minimum 1.2 per cent. Limestone, which was used for the surfacing was put on in three courses, having respective depths, measured loose, of 6 inches, 3 inches, and $\frac{3}{4}$ inch, and a total compacted depth of $6\frac{3}{4}$ inches. Surfacing material to the amount of 1,298 cubic yards was used, and of this 1,005 cubic yards was local stone, while 293 cubic yards was purchased and brought by rail. The local stone was quarried and transported 50 feet to the crusher by means of a tram car. After crushing, it was stored in bins having capacities of 50, 30, and 20 cubic yards, and loaded directly into slat-bottom wagons and dump cars of approximately 1.2 cubic yards capacity. The wagons were drawn by teams and the dump cars by a traction engine. The average haul from the crusher to the road was 4 miles. The stone that was shipped was hauled 70 miles by rail. Water was piped 900 feet for the crusher and hauled 1 mile for the roller and sprinkler. A vitrified clay-pipe culvert at station 9+00 was broken during the surfacing, having been placed too near the surface. In replacing it 26 feet of 18-inch pipe and $2\frac{1}{2}$ cubic yards of concrete were used. At the crusher $45\frac{3}{4}$ tons of fuel were used and 14 tons by the roller. The explosives used at the quarry cost \$118.92.

The equipment consisted of a crusher and engine having a capacity of 150 tons per 10-hour day, slat-bottom wagons, a sprinkler, a roller, hand tools, etc., and a traction engine was hired at \$10 per 10-hour day. Labor and teams cost, respectively, \$0.15 and \$0.35 per hour, and fuel cost \$1.75 per ton.

The total cost of the work was \$3,630.22, which is at the rate of \$0.837 per square yard. The principal items of cost were: Shaping the subgrade, \$374.13; replacing the culvert at station 9, \$55.53; surfacing material, \$366.25; quarrying, \$951.05; crushing, \$254.06; hauling the stone to the road, \$892.35; spreading the stone, \$240.60; sprinkling, \$112.35; rolling, \$350; and loading stone at the car, \$33.90.

This work was resumed on April 18, 1913, and the project was entirely completed on July 12, 1913. During this period five days were lost on account of unfavorable weather and two days from other causes. The last section surfaced had not been graded throughout its length as the section above described had. On this part the maximum cut was $1\frac{1}{2}$ feet and the maximum fill 3 feet; the maximum grade remained 4 per cent, as on the old road. The land adjacent to this section is hilly and the soil is shale clay underlain by a bed of blue marl. In grading, the earth was loosened with plows, hauled with drag scrapers, and spread by hand. Between stations 43 and 54+10 the foundation was of an inferior character. Subdrainage was therefore provided by digging a ditch along the gutter and filling part of it with sandstone and part with limestone, and laying tile drain in the remainder. Cross drains were constructed every 25 feet between the above stations. Other necessary drainage structures had been constructed before the work began. The equipment was the same as that used on the first section described above.

The average haul for the excavation was 200 feet and the maximum haul was 400 feet. The average haul from the crusher to the road was $3\frac{1}{2}$ miles. The surface of this section was constructed entirely of local limestone having good binding qualities and fair wearing qualities. Material was hauled in slat-bottom wagons of 1 cubic yard capacity and dump wagons of 2 cubic yards capacity, and by means of the tractor outfit.

The road was surfaced for 3,900 feet to the following widths: Twenty-four feet wide for 1,110 feet, 16 feet wide for 2,090 feet, and 12 feet wide for 700

feet, making a total surfaced area of 7,609 square yards. It was necessary to grade the road for a distance of 500 feet to a width of 30 feet in cuts and 22 feet in fills, making a total graded area of 1,489 square yards. The surfacing material was spread in three courses, which, when measured loose, were, respectively, 6 inches, 3 inches, and 1 inch deep. The total compacted depth was 6 inches. The material used in the first course ranged in size from 3 inches to 1½ inches; that used in the second course, from 1½ inches to three-fourths inch; and that used in the third course, from three-fourths inch down to and including the dust of fracture. The crown of the finished surface was three-fourths inch to 1 foot.

One thousand cubic yards of earth were excavated, 2,261 cubic yards of surfacing material were crushed, and 2,114 cubic yards used, while 24 tons of coal were used by the crusher and 19 tons by the roller. In constructing the underdrains 1,575 feet of 3-inch vitrified pipe and common land tile and 55 cubic yards of crushed stone were used.

The cost of labor, teams, etc., amounted to approximately the same as in the preceding section. The total cost of the road to the community was \$5,071.99, making the cost per square yard \$0.666.

The principal items of cost were as follows: Excavation to the extent of 1,000 cubic yards, at \$0.141 per cubic yard, \$141.15; shaping the subgrade, 8,676 square yards, at \$0.078 per square yard, \$673.35; 55 cubic yards of limestone for underdrains, at \$2.40 per cubic yard, \$132; 1,575 linear feet of tile, at \$0.034 per foot, \$52.86; labor on the underdrains, \$185.83; trimming the shoulders and ditches, \$20.95; general expenses, \$292.34; quarrying 2,261 cubic yards of limestone, at \$0.551 per cubic yard, \$1,247.32; hauling this stone to the crusher, at \$0.086 per cubic yard, \$195.12; crushing it at \$0.121 per cubic yard, \$273.08; hauling 2,114 cubic yards of stone from the crusher to the road, at \$0.563 per cubic yard, \$1,190.80; spreading it, at \$0.09 per cubic yard, \$190.40; sprinkling 7,609 square yards, at \$0.004 per square yard, \$31.40; rolling 7,609 square yards, at \$0.049 per square yard, \$371.50; and explosives used in the quarry, \$73.89.

It is interesting to note that the cost of hauling the stone from the crusher to the road, a distance of 3½ miles, by means of wagons was approximately \$1 per cubic yard, while the cost of hauling by means of the tractor outfit was only about \$0.21 per cubic yard. The tractor outfit, however, can not be used except during dry weather.

GRAVEL ROADS.

JONESBORO, ARK.—A gravel road leading from Jonesboro eastward toward the State agricultural school was begun on September 23, 1912, and entirely completed on October 25, 1912, with the loss of 5½ days on account of unfavorable weather and 3 days from other causes. The adjacent land is rolling and the soil throughout the length of the road is clay. A section 3,348 feet long was graded for a width of 30 feet in cuts and 24 feet in fills, giving a total area of 9,822 square yards. The gravel surface is 3,050 feet long and 15 feet wide, making a surfaced area of 5,083 square yards. Three timber bridges having a width of roadway of 16 feet were constructed, having respective dimensions as follows: No. 1, length 8 feet 6 inches, clear span 6 feet 6 inches, and height of opening 4 feet 8 inches; No. 2, length 16 feet 8 inches, clear span 15 feet, and height of opening 2 feet 6 inches; and No. 3, length 16 feet 4 inches, clear span 14 feet 8 inches, and height of opening 4 feet 6 inches.

The maximum grade was reduced from 3.7 per cent to 2.5 per cent, while the minimum grade remained 0.1 per cent. The maximum cut was 1.7 feet and the maximum fill 1.4 feet. Two thousand and seventy cubic yards of earth was excavated for an average haul of 350 feet and a maximum haul of 800 feet.

This material was loosened with plows, hauled in drag and wheel scrapers, and spread with shovels.

The surfacing material consisted of sandy chert gravel possessing fair binding qualities and excellent resistance to wear. The gravel was applied in two courses, the first course having a loose depth of 7 inches at the center and 5 inches at the sides, and the second course a loose depth of 4 inches at the center and 3 inches at the sides. The total compacted depth was 8 inches at the center and 6 inches at the sides, and the crown of the finished roadway was three-fourths inch to 1 foot. The gravel for both courses ranged in size from $3\frac{1}{2}$ inches to fine sand. The surfacing material, of which 1,357 cubic yards was used, was delivered on the road at the contract prices of \$1.15 per cubic yard for 1,171 cubic yards and \$1.25 per cubic yard for 186 cubic yards.

The equipment consisted of one 6-horse road machine, one road plow, one 5-ton horse roller, 8 No. 1 wheel scrapers, 4 No. 2 drag scrapers, and hand tools. The grader outfit, including teams and operators, was hired at the rate of \$14 per 10-hour day. Labor cost \$2, teams \$4.67, and foremen \$2.67 and \$4 per 10-hour day.

The total cost of the road to the community was \$2,703.69, which is at the rate of \$0.511 per square yard. The principal items of cost were as follows: Excavation, at \$0.335 per cubic yard, \$693.20; shaping the subgrade at \$0.018 per square yard, \$101; surfacing material, delivered, \$1,579.15; spreading the surfacing material, \$75.80; rolling, \$19.09; explosives, \$3.16; materials for the culverts and stakes, \$12.08; labor for the culverts, \$6.80; trimming the shoulders, \$7.71; incidental expenses, \$109.70; and superintendence, \$96.

COLUMBUS, Miss.—On July 22, 1912, work was begun on a section of the Tuscaloosa road, extending from Columbus eastward toward the Alabama State line, and it was completed on September 16, 1912. The adjacent land is level and the natural soil a sandy clay. The road was graded 20 feet wide for 2,291 feet, making an area of 5,095 square yards. Earth to the amount of 5,778 cubic yards was moved, and the maximum grade was reduced from 5 to 0.1 per cent. The earth was loosened with plows, picks, and shovels, loaded with shovels into wagons, hauled in wagons and drag scrapers, and spread with shovels and a small grader. The average haul was 450 feet and the maximum haul 700 feet. The total area surfaced was 3,564 square yards. Two types of surfacing materials were used—a good cementing gravel for 1,166 feet and a loose pit gravel for 1,125 feet. The former material, donated by an abutting property owner, was spread upon the prepared subgrade in a single course 7 inches thick before being compacted. It compacted readily under the action of traffic, and the surface was maintained in proper shape by frequent dressing with a road grader. The pit gravel was spread upon the clay subgrade to a depth of 6 inches, and it was expected that it would be mixed with the clay by the traffic, but when the representative of the Office of Public Roads left it was still in a loose, uncemented condition. A total of 636 cubic yards of gravel was used.

Drainage structures were constructed as follows: At station 4+25 a reinforced concrete bridge with 18 feet 6 inches of roadway, a span of 15 feet, and 4.2 feet height of opening; and at station 9+70 a reinforced concrete bridge, with 18 feet 6 inches of roadway and 6.5 feet height of opening, and two 15-foot spans. Both bridges were constructed by contract, with the exception of the center pier of the second bridge, which was built under force account.

The equipment consisted of road plows, drag scrapers, a small road grader, and hand tools.

Based on labor at \$1 per day and teams at \$3, the principal items of cost were as follows: Clearing and grubbing, at \$0.017 per square yard, \$84.20; excavation and embankment, at \$0.206 per cubic yard, \$1,189.35; fine grading,

at \$0.007 per square yard, \$11.90; loosening and loading gravel, at \$0.165 per cubic yard, \$104.70; hauling gravel, at \$0.234 per cubic yard, \$148.80; spreading gravel, at \$0.0057 per square yard, \$20.60; trimming shoulders and ditches, \$5.70; culverts, \$1,106.45; and general expenses, \$10. The total cost of the road was \$2,681.70, which is at the rate of \$0.75 per square yard. If the cost of drainage structures is excluded, the cost per square yard is reduced to \$0.442.

BELTON, TEX.—The road leading from Belton eastward toward Temple, approximately 5½ miles long, known as the Air Line Road, was graded, drained, and surfaced with gravel. This road is about equally divided between Belton precinct and Temple precinct, and on account of the separate road organizations in these two separate precincts it was necessary to construct the road in two sections. Each of these sections will be described in turn.

The Belton section.—Work was started on this section on December 26, 1912. Surfacing was started on March 26, 1913; and excavation was completed on May 22, 1913, and surfacing on June 30, 1913. All work was finished on July 3, 1913. Unfavorable weather caused the loss of 16½ days, and 16½ days were lost from other causes.

The earth was loosened by plows, hauled by drag scrapers, and spread by means of a road machine. The maximum cut was 1½ feet and the maximum fill 5.7 feet. The maximum grade was reduced from 6.4 per cent on the old road to 5 per cent on the new road.

The adjacent land is rolling, and the soil for the first 650 feet is loose rock; for the next 925 feet, gumbo; for the next 1,700 feet, sandy; for the next 3,000 feet, sand-clay; for the next 500 feet, gumbo; for the next 600 feet, loose rock; and for the remainder of the distance to station 124—the end of the section—gumbo. A corrugated iron pipe culvert, 12 inches in diameter and 24 feet long, was constructed at station 73+65.

The equipment consisted of 2 road graders, 5 No. 3 drag scrapers, 3 No. 2 drag scrapers, 1 railroad plow, 1 turn plow, 7 wagons, shovels, picks, etc. The wagons were slat-bottom, having a capacity of 1½ cubic yards, and were used for hauling gravel.

The average haul for the excavation was 110 feet, and the maximum haul 600 feet. The average haul from the gravel pit to the road was 4,920 feet, and the average haul of water for the roller 1½ miles.

The natural soil was used in the foundation throughout the road. Gravel for surfacing was obtained from several different sources, and varied from rather poor to excellent in quality. It was spread on the road partly by means of hand raking and partly with a steel drag and a road machine.

The total length of the road graded was 12,606 feet for a width of 32 feet in cuts and 26 feet in fills, making a total graded area of 42,920 square yards. The total length of surface was 12,010 feet, and the width was 24 feet for 925 feet, and 18 feet wide for the remaining distance, making a total surfaced area of 24,637 square yards. The gravel was spread sometimes in one course and sometimes in two courses. The loose depth of the first course ranged from 5 to 10½ inches, and that of the second course from 1½ to 3¾ inches, while the total loose depth ranged from 5 to 10½ inches. The crown of the finished surface varied from three-quarters to 1 inch to 1 foot according to the steepness of the grade.

Earth to the amount of 5,268 cubic yards was moved in grading; and 5,503 cubic yards of gravel was used in surfacing, of which 4,733 cubic yards was purchased and 770 yards donated.

Convict labor cost \$0.60; hired labor from \$0.75 to \$2.50; and teams from \$3 to \$3.50 for a 9-hour day. The total cost of the work was \$4,144.33, which is at the rate of \$0.167 per square yard.

The principal items of cost were as follows: 5,268 cubic yards of excavation, at \$0.143 per cubic yard, \$739.15; shaping the subgrade, at \$0.002 per square yard, \$45.42; 24 feet of culvert pipe, at \$0.50 a foot, \$12; labor for culverts, \$5.75; 4,733 cubic yards of gravel, at \$0.05 per cubic yard, plus \$150 for the pit, \$386.65; loosening and loading the gravel, 5,503 cubic yards, at \$0.15 per cubic yard, \$825.89; hauling 5,503 cubic yards of gravel from the pit to the road, at \$0.318 per cubic yard, \$1,753.10; spreading the gravel, at \$0.054 per cubic yard, \$295.11; working and finishing the surface, \$60.52; trimming the shoulders and ditches, \$18.80; and explosives, \$1.94.

The Temple section.—This section extends from station 124 to station 276+80. The first work was excavation, and this was begun on December 26, 1912, and finished on June 18, 1913. The surfacing was started on March 26, 1913, and finished on July 3, 1913. The road was entirely completed by July 5, 1913. Twenty-two days were lost on account of unfavorable weather and 6.9 days from other causes. Earth in excavation was loosened by plows and hauled in wagons and in drag and wheel scrapers, while rock was loosened with picks, bars, and dynamite, and hauled in wagons. Culverts were constructed as follows: Station 128+10, 12-inch concrete pipe, 30 feet long; station 134+35, 30-inch concrete pipe, 26 feet long; station 148+40, 12-inch concrete pipe, 34 feet long; station 154+10, 42-inch concrete pipe, 56 feet long; and station 172+27, 8 feet by 6 feet reinforced concrete culvert with 18-foot roadway. The maximum cut was 3.2 feet, and the maximum fill, 13.9 feet, and the maximum grade was reduced from 8.6 per cent to 5 per cent. The adjacent land is rolling and the soil varies in character; it is gumbo for the first 3,400 feet, loose rock for the next 500 feet, gumbo for the next 1,200 feet, yellow clay over shale limestone for the next 500 feet, gumbo for the next 1,800 feet, loose rock for the next 1,600 feet, gumbo for the next 1,000 feet, soft ledge limestone for the next 700 feet, and gumbo for the remainder of the distance to station 276+80. The equipment consisted of one 10-ton roller, one 10-barrel tank wagon, one 600-gallon sprinkling wagon, 2 road graders, 1 rooter plow, 1 railroad plow, 1 turn plow, 3 No. 2 wheel scrapers, 6 No. 2 and 2 No. 3 drag scrapers, two 16-foot sections of collapsible culvert forms, slat-bottom wagons, picks, shovels, etc. The wagons had a capacity of approximately $1\frac{1}{2}$ cubic yards and were used for long-haul grading and for hauling gravel.

The average haul for excavation was 140 feet and the maximum haul 950 feet. The average haul from the gravel pit to the road was 10,320 feet. Water was conveniently obtained from a pipe at the roadside. The gravel used was chert and limestone, and it was loaded on the wagons by means of shovels and drag scrapers.

The total length of the road graded and surfaced was 15,223 feet for a width of 32 feet in cuts and 26 feet in fills, making a total graded area of 50,830 square yards. The width surfaced was 18 feet throughout, making the surfaced area 30,446 square yards. Part of the gravel was spread in one course and part in two courses. The loose depth of the first course varied from 4 to $6\frac{1}{2}$ inches, and of the second course from 1 to $5\frac{1}{2}$ inches. The total loose depth varied from $4\frac{1}{2}$ to 10 inches. The crown of the finished surface was from three-fourths inch to 1 inch to 1 foot. Earth to the amount of 5,927 cubic yards and rock to the amount of 145 cubic yards were moved in excavation, and 5,877 cubic yards of gravel was used in surfacing. Two hundred and fifteen sacks of cement, 2,740 pounds of steel, 67 cubic yards of gravel, 2,750 feet, board measure, of lumber, one-half coil of wire, 64 feet of 12-inch concrete pipe, and 36 feet of 30-inch concrete pipe were used in culverts. Convict labor cost \$0.60, hired labor from \$0.80 to \$2, and teams from \$2.20 to \$3.50 per nine-hour day.

The total cost of the road to the community was \$6,221.55, which is at the rate of \$0.204 per square yard or \$2,157.25 per mile. The principal items of cost were 6,072 cubic yards of excavation, at \$0.158 per cubic yard, \$962.48; shaping the subgrade, at \$0.001 per square yard, \$43.28; 100 feet of concrete pipe, at \$0.853 per foot, \$85.31; labor for concrete pipe, \$31.73; 8-foot by 6-foot culvert, \$397; 42-inch pipe culvert, \$350; surfacing material in the pit, \$348.75; loosening and loading, 5,877 cubic yards of surfacing material, at \$0.137 per cubic yard, \$803.47; hauling surfacing material from the pit to the road, at \$0.465 per cubic yard, \$2,733.71; spreading the surfacing material, at \$0.047 per cubic yard, \$273.63; finishing and rolling, \$81.22; trimming the shoulders and ditches, \$22.27; 12 tons of coal, at \$6 per ton, \$72; and incidental expenses, \$16.70.

GRAVEL-MACADAM ROAD.

BENT OAK, MISS.—Work on a road extending from Bent Oak southward toward the Gilmer Road was begun on October 14, 1912, and discontinued because of unfavorable weather conditions, on December 18, 1912. During this time 3 days were lost on account of bad weather. The adjacent land is rolling and the soil is a very stiff post-oak gumbo. For a distance of 2,185 feet the road was graded 24 feet wide in cuts and 20 feet wide in fills, making an area of 5,350 square yards graded, for which 900 cubic yards of material was moved. The maximum grade was reduced from 7.5 to 3.6 per cent. The earth was loosened with plows and picks, loaded by hand and with shovels, hauled with slip and wheel scrapers and dump-board wagons, and spread with shovels and slip scrapers. The average haul was 630 feet and the maximum haul 1,150 feet. Two kinds of material were used for surfacing—a soft limestone and a clay cementing gravel. The limestone was found in ledges at a maximum depth of 3 feet below the surface and an average distance of one-half mile from the road. It was broken by hand into suitable sizes on the road. The gravel, on the other hand, was purchased and delivered in cars at a convenient siding, with a haul of about 750 feet. The road for 1,955 feet was surfaced 12 feet wide with two methods, and the entire area surfaced was 2,607 square yards. According to the first method, which was followed in surfacing 1,720 square yards, a foundation course of rock was spread with shovels and rakes 6 inches deep after compacting, and upon it a surface course of gravel was spread with a road grader to a depth of 4 inches after compacting, while the second method, which was used in surfacing the remaining 887 square yards, consisted in spreading a single course of rock to a depth of 6 inches after compacting. The crown adopted for both types of road was 1 inch to 1 foot. The total volume of rock was 450 cubic yards and of gravel 260 cubic yards. Cross drains were constructed as follows: At station 0+75 a 16-inch cast-iron culvert 21 feet long and at station 19+17 a reinforced concrete culvert of 3 feet span, 30-inch height of opening, and 20 feet length.

The equipment consisted of road and turn plows, 6 slip scrapers, 2 wheel scrapers, 1 road grader, and 1 split-log drag. The estimated cost of the convict labor, which was used exclusively, was \$1 per day, and, while all teams used on the work were loaned to the local authorities free of charge, a money value of \$3 per day per team was assumed for these contributions. This corresponded with local prices for teams.

The principal items of cost, based on the above prices, were as follows: Clearing and grubbing, \$46.55; excavation and embankment, at \$0.55 per cubic yard, \$494.36; shaping the subgrade, at \$0.028 per square yard, \$72.69; quarrying rock, at \$0.91 per cubic yard, \$410.83; hauling rock, at \$0.47 per cubic yard, \$211.14; placing, spreading, and "napping" rock, at \$0.097 per cubic yard,

\$43.75; gravel, \$54; freight on gravel, \$86; unloading gravel cars at siding, at \$0.043 per cubic yard, \$11.29; loading gravel wagons, at \$0.154 per cubic yard, \$40; hauling gravel, at \$0.125 per cubic yard, \$32.44; placing and spreading gravel, at \$0.038 per cubic yard, \$10; trimming ditches and shoulders, \$62.86; culverts, \$135.59; and general expenses, \$34.65.

The total cost of the road was \$1,746.15, which is at the rate of \$0.686 per square yard for the gravel section and \$0.406 per square yard for the rock section.

BRICK-CINDER ROAD.

COLUMBUS, MISS.—The work at Columbus, Miss., which consisted in grading and surfacing a section of what is known as the Military Road, extending from Columbus toward the Alabama State line, was begun on September 18, 1912, and completed on October 9, 1912. The adjacent land is hilly, and the natural soil is sand and clay. For 2,128 feet the road was graded 30 feet wide in cuts and 20 feet in fills, giving an area of 2,615 square yards. A total volume of 1,696 cubic yards of earth was moved, resulting in lowering the maximum grade from 1.5 to 0.4 per cent. The earth was loosened with a plow, picks, and shovels, hauled in wagons and slip scrapers, and spread with shovels. The average haul was 250 feet and the maximum 900. The surfacing materials consisted of brickbats and brick-kiln cinders, donated by a local brick manufacturer. Both materials were loaded on dump-board wagons at the brickyard, hauled an average distance of one-half mile, and spread upon the prepared subgrade with shovels and potato hooks. The brickbats, which were used in the foundation course, were broken with hammers at the road, and were spread to a width of 14 feet and a depth of 4 inches after compacting, while the surface course was composed of the cinders spread to a width of 16 feet and a depth of 4 inches after compacting. The road was compacted principally by the action of traffic, but a short section was rolled with a road roller loaned by the authorities of the city of Columbus. The road was surfaced for 1,243 feet, and the area of the foundation course was 1,933 square yards, requiring 322 cubic yards of brickbats. The area of the surface course was 2,210 square yards, upon which 343 cubic yards of cinders were used. The road is one of the most heavily traveled roads in the county, but judging from results obtained upon a similar road in the same locality, it is expected that the surface will wear well if it is given proper attention.

The equipment consisted of a road plow, slip scrapers, and a small road grader. With labor at \$1 per day and teams at \$3, the principal items of cost were as follows: Excavation, at \$0.14 per cubic yard, \$236.15; clearing and grubbing, \$20.75; trimming the shoulders and ditches, \$9.40; labor on the pipe culvert, \$2.75; loading brickbats, at \$0.202 per cubic yard, \$65.35; hauling brickbats, at \$0.413 per cubic yard, \$133.25; spreading brickbats, at \$0.063 per cubic yard, \$20.45; loading cinders, at \$0.087 per cubic yard, \$63.70; hauling cinders, at \$0.323 per cubic yard, \$110.65; spreading cinders, at \$0.035 per cubic yard, \$12.10; and general expenses, \$7.20. The total cost of the road was \$681.75, which is at the rate of \$0.26 per square yard for the completed section.

SAND-CLAY ROADS.

BROOKSVILLE, FLA.—Work was started on the Bayport Road, which leads west from Brooksville toward Bayport, on March 10, 1913, and was completed on April 16, 1913. The land adjacent to the road is rolling and the soil is clay from station 0 to station 19, and a natural mixture of sand and clay from station 19 to station 24. The maximum cut was 2 feet and the maximum fill

2½ feet. The maximum grade was reduced from 4½ per cent to 3½ per cent. The equipment consisted of one 2-horse plow, 5 drag scrapers, one 6-horse road grader, flat-bottom wagons, picks, shovels, etc. Labor cost \$1.75 and teams \$5 per 10-hour day.

The improvement consisted in grading and shaping the existing road and surfacing it with a sand-clay mixture. The earth was loosened with plows and hauled in wagons and on drag scrapers for an average haul of 700 feet and a maximum haul of 1,900 feet. The material was spread and the road shaped by means of the road grader. One drainage ditch was constructed leading away from the road at station 25. The ditch was 5 feet wide by 1 foot deep by 300 feet long. Clay for surfacing was hauled an average distance of one-half mile, and the sand an average distance of three-fourths of a mile. These materials were spread in uniform layers of 7 inches and 3 inches, respectively, and thoroughly mixed.

The road was then shaped so that the crown of the finished surface was 1 inch to 1 foot. Five days were lost on account of unfavorable weather and six days from other causes. The weather and labor conditions were largely responsible for the high cost of this work.

The road was graded to a length of 2,400 feet, with a width of 28 feet in cuts and 20 feet in fills. The entire length was surfaced to a width of 16 feet, making the surfaced area 4,267 square yards. Earth to the amount of 1,450 cubic yards was moved in excavation, and 1,500 cubic yards of surfacing material was used. The total cost of the road to the community was \$1,351.51, which is at the rate of \$0.317 per square yard. The principal items of cost were: Excavation, 1,450 cubic yards, at \$0.30 per cubic yard, \$432; shaping the subgrade, at \$0.031 per square yard, \$130.63; clearing and grubbing, \$15.50; trimming the shoulders and ditches, \$55.38; excavating 303.3 cubic yards of sand, at \$0.15 per cubic yard, \$45.50; loosening and loading 830 cubic yards of clay, at \$0.109 per cubic yard, \$90.49; hauling clay, 830 cubic yards, at \$0.265 per cubic yard, \$220; loosening and loading 660 cubic yards of sand, at \$0.116 per cubic yard, \$76.38; hauling sand, 660 cubic yards, at \$0.24 per cubic yard, \$158.75; spreading sand, 660 cubic yards, at \$0.019 per cubic yard, \$12.25; spreading clay, 830 cubic yards, at \$0.021 per cubic yard, \$17.50; mixing sand and clay, 4,267 square yards, at \$0.0035 per square yard, \$15; final shaping, at \$0.0035 per square yard, \$15; and general expenses, \$67.13.

QUITMAN, GA.—Work was begun on a sand-clay road extending from Quitman toward Spain, on January 30, 1913, and completed on February 21, 1913, with the loss of five days on account of bad weather. The adjacent land is rolling and the natural soil is sand from station 0 to station 15, clay from station 15 to station 22, sand from station 22 to station 30, clay from station 30 to station 34, sand from station 34 to station 44, clay from station 44 to station 48, and sand from station 48 to station 61.

A total length of 6,100 feet was graded 30 feet wide in cuts and 20 feet wide in fills, making 15,000 square yards. Earth was excavated to the amount of 1,050 cubic yards, and the average haul was 375 feet and the maximum haul, 500 feet. Throughout its entire length the road was surfaced to a width of 14 feet, making 9,489 square yards. The sand-clay surface was constructed as follows: The sand and clay were spread uniformly in two courses of 4 inches and 8 inches in loose depth, respectively. These materials were then thoroughly mixed first with a plow and then with a disk harrow, after which the road was shaped with a road grader. It was immediately opened to traffic and as ruts were formed they were filled by dragging. Clay to the amount of 1,590 cubic yards was hauled to the road, dumped, and spread by hand with shovels. Sand was used to the amount of 790 cubic yards, a part of which was hauled and

spread by hand while the rest was obtained from the sides of the road and spread with the road grader. The binding qualities of the clay and the wearing qualities of the clay and sand appear to be very good.

Cross drains, 28 feet long, were constructed of 10-inch and 24-inch sewer pipe at stations 25 and 55, respectively.

The equipment consisted of one 6-mule grader, 1 rooter plow, 1 turn plow, 1 disk harrow, wagons, and hand tools.

The total cost of the road was \$513.55, which is at the rate of \$0.054 per square yard. The principal items of cost were as follows: Excavation, at \$0.11 per cubic yard, \$115.05; shaping the subgrade, at \$0.002 per square yard, \$19.50; loading and hauling clay, at \$0.15 per cubic yard, \$235.59; spreading clay, at \$0.015 per cubic yard, \$23.10; loading and hauling sand, \$30.72; spreading sand, \$2.40; mixing, at \$0.0025 per square yard, \$24.26; trimming shoulders, \$8.80; stripping and refilling clay pits, \$19.84; moving fences, \$4.65; and culverts, \$29.64. The above costs were based upon a labor cost of \$0.60 per day of 10 hours, and a cost for teams of \$1 per day of 10 hours. Convict labor and county teams were used.

TALBOTTON, GA.—Work on the sand-clay road known as the Centerville Road, which was begun during the fiscal year 1912, but which, owing to unfavorable weather conditions, was discontinued on January 6, 1912, was resumed on August 20, and finally completed on August 24, 1912. During the previous year the road was graded 30 feet wide for 3,525 feet and surfaced 14 feet wide for 1,950 feet. When the work was resumed this surface was found to be in excellent condition with the exception of slight inequalities resulting from a lack of proper care as the road dried out in the spring. The surface, constructed last year, was extended 1,625 feet, with a width of 14 feet, making 2,528 square yards, upon which 614 cubic yards of surfacing material was used. This material, which was hauled an average distance of 1 mile, consisted of red clay and fine loamy sand, and the clay was spread 4 inches deep before compacting and the sand 8 inches. As in the previous work, the crown adopted was three-fourths inch to 1 foot. The section between stations 34+25 and 35+25 was slightly inferior owing to the fact that the subgrade was wet and had not fully settled when the surface was laid. An additional amount of sand was used on this section, however, and it is expected that it will eventually be as good as the rest of the road. The force employed was the regular county road force, and was made up of 23 convicts, 3 guards, a superintendent, and 19 mules. Convict labor cost \$0.50 per day and teams \$1. The principal items of cost were as follows: Loading surfacing material, at \$0.062 per cubic yard, \$38.25; hauling surfacing material, at \$0.091 per cubic yard, \$56; spreading surfacing material, at \$0.001 per square yard, \$2.25; mixing, at \$0.0075 per square yard, \$18.50; shaping, at \$0.002 per square yard, \$5; repair and maintenance, \$10; and camp care for convicts, \$17.50, making the total cost of the work performed this year \$147.50. The cost of work previously completed was \$1,067.31, and the total cost of the road was, therefore, \$1,214.81, which is at the rate of \$0.22 per square yard.

HOUSTON, MISS.—A section of sand-clay road was constructed in Chickasaw County, leading north from Houston toward Houlka. This road is locally known as the Pontotoc Road. A survey was made on April 22, 1913, and grading was begun on April 25, 1913. The road, as originally planned, was not completed under the supervision of the Office of Public Roads. This was due to the fact that sufficient force was not employed to justify continuing the assignment. On May 29, 1913, the work was turned over to a competent foreman with a view to continuing it after the office representative was withdrawn. The land adja-

cent to the road is slightly rolling and the soil varies from a heavy plastic clay to a loam clay rich in lime, with blue clay occurring from station 17 to station 20. The maximum cut was 0.3 foot and the maximum fill 1.6 feet. The maximum grade was reduced from 3.4 to 2.9 per cent. The minimum grade remained level. Labor cost \$1 and teams \$3 per 10-hour day.

The road was constructed by grading and shaping the old road, providing the necessary drainage structures, and surfacing with a mixture of sand-clay. The sand used in surfacing was obtained from a pit and mixed with clay from the road. The sand was hauled in ordinary farm wagons having a capacity of approximately 1 cubic yard, and the mixing was done with disk and spike-tooth harrows and plows. The final finishing and shaping was done with a split-log drag. Two reinforced concrete pipe culverts were constructed, each 16 feet in length. The one at station 33 had a diameter of 30 inches and the other at station 42+81 had a diameter of 24 inches. The forms for these culverts consisted of collapsible cylinders and the reinforcement of heavy woven-wire fencing. The end walls of the 30-inch culvert were 10 feet long and 9 inches thick. Those of the 24-inch culvert were 9 feet long and 8 inches thick. The equipment consisted of one 8-horse road grader, 1 road plow, 2 No. 1 drag scrapers, 1 split-log drag, 1 disk harrow, 1 spike-tooth harrow, collapsible culvert forms, picks, shovels, etc.

The total length graded was 4,080 feet. The width graded was 26 feet in cuts and 20 feet in fills, making a total graded area of 11,787 square yards. For 2,450 feet the road was prepared for surfacing, but only 1,150 feet was finished. The width surfaced was 14 feet, making a total surfaced area of 3,344.4 square yards. The sand was spread to a loose depth of 6 inches and the crown of the finished roadway was 1 inch to 1 foot. In the excavation 692 cubic yards of material was moved, with an average haul of 10 feet and a maximum haul of 50 feet. Sand to the amount of 583.3 cubic yards was used for surfacing and the average haul from the sand pit to the road was 1.7 miles. In the construction of the culverts 12.3 cubic yards of concrete was used, and the gravel for this work was hauled by rail for a distance of 76 miles, and then by wagon 0.6 mile from the siding to the road.

Cement cost \$0.55 a sack and gravel \$1.155 per cubic yard f. o. b. siding. The total cost of the road to the community was \$696.43, and the cost per square yard, taking each item of cost separately and disregarding culverts, was approximately \$0.158. The principal items of cost were as follows: Clearing and grubbing, \$7.25; rough grading 692 cubic yards, at \$0.0942 per cubic yard, \$65.20; preparing the subgrade, 3,700 square yards, at \$0.0057 per square yard, \$21.05; loading sand, 583.3 cubic yards, at \$0.0612 per cubic yard, \$35.70; hauling sand, 583.3 cubic yards, at \$0.6182 per cubic yard, \$360.60; spreading sand, 583.3 cubic yards, at \$0.031 per cubic yard, \$18.10; mixing 3,344.4 square yards, at \$0.0086 per square yard, \$28.90; shaping 6,211.1 square yards, at \$0.0012 per square yard, \$7.25; superintendence, \$38.40; and incidentals, assembling tools, etc., \$4.80. The total cost of the drainage system was \$109.18, and this figure may be divided into the following items: Labor on the ditches, \$16.80; excavating for the culverts and backfilling over them, \$11.40; hauling the gravel, cement, and water 0.6 mile, \$14.05; labor on the forms, \$4.20; mixing and placing the concrete, \$8; 18 cubic yards of gravel, at \$1.155 per cubic yard, \$20.79; 52 sacks of cement, at \$0.55 per sack, \$28.60; 50 feet b. m. lumber, at \$16 per thousand, \$0.80; 8 rods of heavy woven-wire fence, at 28 cents per rod, \$2.24; 6 pounds of nails, at \$0.05 per pound, 30 cents; and 2 gallons of linseed oil, at \$1 per gallon, \$2.

Moscow, Miss.—A section of clay road 4,150 feet in length at Moscow, Miss., was partially relocated, graded, and surfaced with sand-clay. The graded width

was 30 feet and the surfaced width 17 feet. This road lies between De Kalb and Moscow, and is a part of what is known as the Jackson Road. The adjacent land is hilly. Work was begun on September 20, 1912, and was completed on November 5, 1912. The only sand available for surfacing was very fine grained and of poor quality. It was obtained from a pit and hauled to the road in farm wagons for approximately 15 miles.

The grading was done with a road machine, a railroad plow, and five slip scrapers. The total area graded was 13,833 square yards, and the cost of grading was \$282.04. No record was kept of the quantity of material moved in grading. The subgrade was shaped for surfacing at a cost of \$0.003 per square yard, or \$20.58 for the 7,839 square yards surfaced.

Sand to the amount of 1,524 cubic yards was used for surfacing, and the cost of surfacing was distributed as follows: Hauling 1,524 cubic yards of sand, at \$0.49 per cubic yard, \$743.20; spreading 1,524 cubic yards of sand, at \$0.007 per cubic yard, \$10.60; and mixing 7,839 square yards of surface, at \$0.006 per square yard, \$48.54; making the total cost of surfacing \$802.34.

The other items of expense were: Ditching, \$25.55; clearing and grubbing, \$41.38; excavation for a bridge, \$2.80; general expenses (foreman, coke, etc.), \$112.42; and miscellaneous expenses (camp, trips for provisions, etc.), \$34.50. This makes a total cost to the community of \$1,321.61, or a cost per square yard of \$0.096.

All grading and other work on the road was done by the county convict force with county teams, and the cost per convict was \$0.40 per day, and the cost per team \$0.80 per day. The surfacing material was hauled by contributed labor, the money value of which has been rated at \$1 per day per man and \$2.50 per day per team.

CALYPSO, N. C.—A section of road leading from Calypso southeast toward Kenansville was graded and surfaced between September 4 and September 14, 1912. The adjacent land is slightly rolling and the soil is sandy throughout the length of the section. The grading consisted in plowing the ditches and bringing the road to the proper cross section with a road machine. A small amount of material was moved for an average distance of 50 feet with drag scrapers. For 1,650 feet the road was graded 24 feet wide and surfaced 14 feet wide, making the area graded 4,400 square yards and the area surfaced 2,563 square yards. The crown of the finished roadway was three-fourths inch to 1 foot. Clay to the amount of 248 cubic yards was hauled an average distance of 2,400 feet, and 55 cubic yards of sand was hauled an average distance of 1,760 feet. Farm wagons having an approximate capacity of 1 cubic yard were used for hauling both sand and clay. They were loaded and unloaded with shovels. Two corrugated-iron culverts were ordered for this work, but were not received before the surfacing was completed. Directions were furnished for placing them.

The equipment consisted of 1 road machine, 1 rooter plow, 1 turn plow, 1 split-log drag, 2 drag scrapers, 1 disk harrow, farm wagons, and hand tools. Labor cost \$1 and \$1.50 per day and teams cost \$1.20 and \$2.50 per day. The total cost of the work was \$133.60, which is at the rate of \$0.0521 per square yard. The principal items of cost were: Grading and shaping the subgrade, \$38.60; loading sand, \$3.75; hauling sand, \$6.25; spreading sand, \$1.50; loading clay, \$22.65; hauling clay, \$49.25; spreading clay, \$5.50; mixing clay and sand, \$4.80; and final shaping with a drag, \$1.60.

JERUSALEM, N. C.—A sand-clay road running from Cooleemee northeast to Jerusalem was begun on September 3, 1912, and completed on October 18, 1912. The land adjacent to the road is rolling and the soil varies from "black jack"

gravel to micaceous clay. This road had been graded to a width of 24 feet in cuts and 18 feet in fills, and the drainage structures were all completed before the object-lesson work was begun.

The sand for use in surfacing was loosened with plows, loaded with hand shovels, hauled approximately $1\frac{1}{4}$ miles in flat-bottom wagons, and spread with grader and by hand. The subgrade prepared for surfacing was 20,020 feet long and 16 feet wide, making a total area of 35,590 square yards. The same area was given a sand-clay surface 6 inches thick after compacting, with a crown of three-fourths of an inch to 1 foot. For the surfacing 4,820 cubic yards of material was used, approximately 3,000 cubic yards of which had to be purchased. The cost of labor was \$1.25 per day, and of teams \$3 per day.

The total cost of the work was \$1,799.61, which is at the rate of \$0.0506 per square yard. The principal items of cost were: Loading sand, at \$0.0605 per cubic yard, \$291.61; mixing surfacing materials, at \$0.001 per square yard, \$37.25; shaping, at \$0.0015 per square yard, \$53.25; spreading sand, at \$0.0137 per cubic yard, \$66; hauling sand, at \$0.2546 per cubic yard, \$1,227; purchase of sand pits, \$105.25; and general expenses, including water boy, etc., \$19.25. The cost of superintendence, which is included above, was 6.32 per cent of the total cost.

LEXINGTON, N. C.—A sand-clay surface was constructed at Lexington on Fifth Avenue south from Center Street, toward the southbound railroad station. The work was begun on July 22, 1912, and was completed on August 22, 1912. The adjacent land is rolling and the natural soil is clay of a plastic nature but lacking in toughness.

The first work was grading. The earth was loosened by means of a traction engine and a road plow, loaded and hauled with drag scrapers, wheel scrapers, and wagons, and spread with shovels. The maximum cut was 4 feet and the maximum fill 3 feet. The maximum grade was reduced from 3 per cent to 1 per cent.

The equipment consisted of 3 No. 2 wheel scrapers, 6 No. 2 drag scrapers, 2 plows, three $1\frac{1}{2}$ -cubic-yard dump wagons, one 12-horsepower traction engine, picks, shovels, etc. The average haul for excavation was 150 feet and the maximum haul 400 feet. The sand mixed with the clay for surfacing was obtained from a pit and hauled for an average distance of 3 miles in 1-cubic-yard flat-bottom wagons. The quality of the sand was excellent for the purpose for which it was used. Free labor cost \$1.25 and \$1.50, and foreman \$3 per 10-hour day. Convict labor was estimated at \$1 per day, and teams cost from \$2 to \$3 per day.

The total length graded was 3,000 feet, and the width graded, both in cuts and fills, was 30 feet, making the total area graded 10,000 square yards. The entire length of 3,000 feet was surfaced for a width of 18 feet, making the area surfaced 6,000 square yards. The compacted depth of surfacing material was 4 inches and the crown three-fourths of an inch to 1 foot. The earth excavation amounted to 3,975 cubic yards, and the sand used for surfacing amounted to 815 cubic yards. The total cost of the work was \$1,177.45, which is at the rate of \$0.196 per square yard of surfaced area. The principal items of cost were: Excavation, 3,975 cubic yards, at 11 cents per cubic yard, \$440.35; hauling 815 cubic yards of sand, at 80 cents per cubic yard, \$652; spreading 815 cubic yards, at \$0.016 per cubic yard, \$12.75; mixing the sand and clay, \$60.60; sprinkling, \$6; and general expenses, \$5.75.

ARANSAS PASS, TEX.—A section of Commercial Street extending east from Wheeler Avenue to the city limits was given a sand-clay surface during the past fiscal year. Excavation was started on November 21, 1912, and the work was entirely completed by December 16, 1912, with the loss of only one day

on account of unfavorable weather. A total length of 5,000 feet was graded to a width of 16 feet in cuts and 18 feet in fills and surfaced to a width of 16 feet throughout, making a total area of 8,890 square yards for the surfaced roadway.

The adjacent land is approximately level and the soil consists of fine loose sand. Eight hundred and ninety cubic yards of earth was moved in excavation, with a maximum cut of 2 feet and a minimum fill of 2.5 feet. The excavated material was loosened with plows, hauled for an average distance of 200 feet in wheel scrapers and dump wagons, and spread with a road machine. The maximum and minimum grades remained respectively 0.2 per cent and level.

In order to increase the stability of the sand foundation, a layer of sea moss, 2 inches thick before compacting, was spread before applying the surfacing material, and 117 wagon loads of moss were used. The surfacing material, which consisted of a natural sand-clay mixture, was then spread to a depth of $7\frac{1}{2}$ inches loose or 5 inches compacted, and a crown of 1 inch to 1 foot was given the roadway. The material for the surfacing amounted to 1,823 cubic yards. It was hauled 1,000 feet in flat-bottom wagons and spread with a road machine. This material was delivered by contract at \$0.50 per cubic yard.

Labor cost \$1.50 and teams cost \$3.50 and \$4 per 9-hour day. The total cost of the road to the community was \$1,397.13, which is at the rate of \$0.157 per square yard. The principal items of cost were as follows: Excavation, at \$0.348 per cubic yard, \$309.58; surfacing material, delivered, at \$0.50 per cubic yard, \$911.50; spreading the surfacing material, at \$0.011 per square yard, \$20; loading and spreading the moss, \$82.05; shaping the finished roadway, \$8; and superintendence and general expenses, \$66.

CORPUS CHRISTI, TEX.—During the fall of 1912 a sand-clay road was constructed at Corpus Christi, extending in a northwesterly direction toward Calallen. Work was begun on October 8, 1912, and completed on November 29, 1912, and during this time five days were lost on account of bad weather. The land adjacent to the road is rolling and the nature of the soil is sand-clay throughout, with clay predominating from station 0 to station 20, while from station 20 to station 54 sand predominates. In all, 5,400 feet was graded 45 feet wide, making 27,000 square yards. The maximum cut was 1 foot and the maximum fill 3.5 feet, and the grade was reduced from 6.5 per cent to 5 per cent. The volume of excavation was 6,700 cubic yards, and the average haul was 200 feet and the maximum haul 700 feet. Throughout its entire length the road was surfaced with a natural sand-clay mixture of good binding and wearing qualities for a width of 16 feet and a compacted depth of 6 inches, making 9,600 square yards of surface covered, or 2,140 cubic yards of material used. The material was spread with a road grader.

The crown adopted was one-half inch to 1 foot. The road was so located that the principal problem presented was that of securing proper drainage. To this end the grade was raised and six existing culverts were replaced by three new ones of greater capacity, constructed as follows: At station 11+20 a 24-inch vitrified clay pipe 39½ feet long; at station 24+20 two 36-inch corrugated metal pipes 24 feet long, replacing two 24-inch vitrified clay pipes; at station 43+00 a reinforced concrete box culvert, 6 feet in span, 4½ feet in height of opening, and 22 feet in length; and at station 51+50 an old 24-inch vitrified clay pipe culvert was allowed to remain in place. All of the pipe used was found on the ground, and the concrete culvert was built by contract.

The equipment consisted of 1 road grader, 4 wheel scrapers, 5 drag scrapers, 1 plow, three 1½-cubic-yard wagons, 1 disk harrow, and 1 tooth harrow.

Labor cost \$1.40 per 10-hour day and teams \$1. The principal items of cost were as follows: Excavation, at \$0.107 per cubic yard, \$715.70; shaping subgrade, at \$0.0007 per square yard, \$10.89; clearing and grubbing, \$44.99; hauling the surfacing material, at \$0.065 per cubic yard, \$138.84; mixing, at \$0.0011 per square yard, \$10.92; labor for pipe culverts, \$33.65; contract price of end walls for pipe culverts, \$66; contract price of box culvert, \$154.50; and cost of hauling materials for the concrete, not included in contract price, \$43.25. The total cost of the road was \$1,218.74, which is at the rate of \$0.127 per square yard.

JEWETT, TEX.—Work was started on August 22, 1912, on a sand-clay road running from Jewett westward toward Newby and completed on September 7, 1912. The land adjacent to the road is rolling, and the soil is sandy throughout the section surfaced. In grading, the earth was loosened by plowing and hauled in drag scrapers for an average distance of 50 feet. A section 10,500 feet long was graded for a width of 40 feet and surfaced for a width of 14 feet, making the area graded 46,666 square yards and the area surfaced 16,333 square yards. Earth to the amount of 4,350 cubic yards was moved in the excavation, and 4,100 cubic yards of clay was used for surfacing. The clay was hauled for an average distance of 1,350 feet and spread to a depth of 9 inches, measured loose, but on account of the continued dry weather it could not be successfully mixed with the sand. Specifications were furnished by the representative of the Office of Public Roads, however, for properly mixing the materials when the weather became favorable, and this part of the work was let to contract. Five wooden culverts, 24 feet in length, were constructed, with the following cross sectional dimensions: Two 4 feet by 2 feet, one 10 feet by 2½ feet, and two 16 feet by 3 feet. Three thousand seven hundred and fifty feet b. m. of pine timber and 24 oak posts were used for these culverts.

The equipment consisted of one 2-horse blade ditcher, plows, slat-bottom wagons, and hand tools. Labor cost \$1.75 per 10-hour day and teams \$4. The total cost of the work was \$3,017.08, which is at the rate of \$0.184 per square yard. The principal items of cost were: Clearing and grubbing, \$28.75; excavation and embankment, \$608.75; loosening and loading clay, \$637.75; hauling clay, \$1,183.75; spreading clay, \$74.75; trenching for clay at the side of the road, \$30; shaping with the grader, \$27.50; contract price for mixing, \$150; materials for culverts, \$121.44; labor for culverts, \$51.76; superintendence, \$75; and general expenses, \$27.63.

PEARSALL, TEX.—A section of road in Frio County leading northeast from Pearsall toward Bigfoot, known as the Sand Hollow Road, was improved by surfacing with sand clay. The work was begun on February 20, 1913, and continued until March 31, 1913. Eight days were lost on account of rain and 7½ days for other reasons. The adjacent land is rolling and the soil is a fine sandy loam. The maximum and minimum grades remained respectively 2 per cent and level. The existing grade of this road was such that the only grading necessary was done with the road machine. The only exceptions to this were at stations 23 and 27, where the material obtained in uncovering the clay pit was hauled to fill several holes in the road. Labor cost from \$1.10 to \$1.25 and teams \$3 per 10-hour day.

The road was constructed by first carefully shaping it with a road machine and then spreading a wearing course of clay over the surface. The road was then reshaped by means of the road machine. The clay used for surfacing contained a considerable amount of sand, and possessed excellent binding and wearing qualities. It was spread by hand with shovels and hose, and was obtained from pits and hauled in 1-cubic-yard slat-bottom wagons. At station

37 a wooden box 1½ by 2 by 24 feet was constructed. This was the only drainage structure provided. The equipment consisted of 1 road machine, 8 ¼-yard drag scrapers, 8 slat-bottom wagons, 1 heavy road plow, picks, shovels, etc.

The total length of the road was 4,700 feet and the width both in cuts and fills was 26 feet, making a graded area of 13,578 square yards. The entire length of 4,700 feet was prepared for surfacing, but only 4,200 feet was surfaced. The width of the surface was 15 feet, making a total surfaced area of 7,000 square yards. The surfacing material was spread to a depth of 8 inches compacted and given a crown of three-fourths inch to 1 foot. The clay used for surfacing amounted to 1,556 cubic yards and was hauled for an average distance of 1,050 feet. In constructing the wooden box culvert at station 37, 406 feet b. m. No. 1 pine was used. The total cost of the road to the community was \$926.90, making the cost per square yard of surfaced area \$0.132. The principal items of cost were: Grading and shaping the subgrade, \$42.40; filling holes with material stripped from the clay pits, \$22.25; timber for the culvert, \$12.75; stripping the clay pits, \$143; loosening and loading clay, 1,556 cubic yards at \$0.183 per cubic yard, \$284.72; hauling clay, 1,556 cubic yards at \$0.228 per cubic yard, \$355.50; spreading clay, 1,556 cubic yards at \$0.032 per cubic yard, \$50.70; dragging, \$11.70; and trimming shoulders, \$3.88.

SAN ANTONIO, TEX.—A section of the road leading from San Antonio south toward Laredo was improved by grading and surfacing with sand and clay. The section is 1 mile in length and approximately 20 miles south of San Antonio. The work was started on January 7, 1913, and completed on February 14, 1913, with the loss of 5½ days on account of rain and bad weather. The adjacent land is rolling, and the soil is a sandy loam upon a clay subsoil throughout the entire road. The maximum cut was 1.7 feet and the maximum fill 1.6 feet. The maximum grade was reduced from 3.7 to 2.8 per cent. Labor cost \$1.50 and teams \$3.45 per nine-hour day.

The road was constructed by spreading a surface course of clay over the natural sand soil used in the foundation. At stations 4+30 and 37+30, where streams are forded, it was necessary to construct stone curbing on either side of the clay surface to protect it from washings. The curb at station 4+30 was 20 feet by 12 inches by 18 inches, and that at station 37+30 was 24 feet by 12 inches by 18 inches.

The road was graded for a total length of 5,280 feet. The width in cuts was 40 feet and in fills 24 feet, making the total area graded 23,467 square yards. The entire length of 5,280 feet was surfaced to a width of 16 feet, making the surfaced area 9,387 square yards. In grading it was necessary to excavate 2,775 cubic yards of earth, and 1,825 cubic yards of clay was used in surfacing. The earth was loosened with plows and hauled a short distance with wheel and Fresno scrapers. The clay was obtained from pits and hauled an average distance of 305 feet in wagons. The equipment consisted of 1 eight-horse road grader, 1 disk harrow, 2 plows, 1 spike-tooth harrow, 5 No. 1 wheel scrapers, 3 five-foot Fresno scrapers, 1 three-foot Fresno scraper, 2 No. 2 slip scrapers, wagons, picks, shovels, etc.

The clay was spread to a loose depth of 7 inches, and the crown of the finished surface was three-fourths inch to 1 foot. The total cost of the road to the community was \$1,261.57, which is at the rate of \$0.134 per square yard. The principal items of cost were as follows: Clearing and surfacing the entire road, \$81.25; moving and rebuilding fences, \$73.34; moving a house from the right of way, \$19.56; constructing curbing, 2.4 cubic yards, at \$2.24 per cubic yard, \$5.38; excavating 2,775 cubic yards of earth, at \$0.1140 per cubic yard, \$318.86; loading, hauling, and spreading 1,825 cubic yards of clay, at \$0.2864 per cubic yard, \$522.65; stripping clay pits, \$52.91; back-filling clay pits, \$88.20; mixing

clay and sand, 9,387 square yards, at \$0.0069 per square yard, \$64.78; and shaping the surface, 23,467 square yards, at \$0.0015 per square yard, \$34.64.

FRANKTOWN, VA.—A sand-clay road leading from Franktown toward Eastville and known as the Eastville Road was begun on September 4, 1912, and left as completed on October 14, 1912. The road subsequently became unsatisfactory, however, and a representative of the Office of Public Roads was detailed to investigate the causes and to supervise such additional work as the conditions seemed to warrant. Work was resumed on January 20, 1913, and the project finally completed on February 1, 1913. Altogether 4 days were lost on account of bad weather.

The land adjacent to the road is rolling, and the soil is sand from station 0 to station 12; clay from station 12 to station 15; sand from station 15 to station 25; and clay from station 25 to station 34. The maximum grade was reduced from 5 per cent to 2 per cent, and the maximum cut was 5 feet and the maximum fill 4 feet. In grading, the earth was loosened with plows, hauled with drag scrapers, and spread with shovels. The total amount moved was 1,590 cubic yards. For 3,400 feet the road was graded 30 feet wide and surfaced 15 feet wide, giving an area of 11,333 square yards graded and 5,666 square yards surfaced. Clay was spread to a depth varying from 4 inches to 12 inches and mixed with an 8-inch course of sand. The crown of the finished road was 1 inch to 1 foot.

The total cost of the road to the community was \$670.60, which is at the rate of \$0.118 per square yard. The principal items of cost were: Grading, \$289.31; clearing and grubbing, \$61.27; shaping the subgrade, \$19.50; loading and hauling the clay, \$137.75; loading and hauling the sand, \$87; mixing the sand and clay, \$26.90; shaping, \$25.37; trimming the shoulders, \$8.75; and constructing road intersections, \$14.75. Labor cost \$1.25 per 10-hour day and teams \$2.50, \$3, \$4, and \$4.25.

SAND-GUMBO ROAD.

COLUMBUS, NEBR.—A section of sand-gumbo road extending northwest from the Platte River toward Columbus was constructed during the fiscal year 1912 and was described in the last annual report of the Office of Public Roads. The work was resumed on August 19, 1912, and an additional section 3,002 feet long was graded to a width of 32 feet in cuts and 24 feet in fills and given a sand-gumbo surface 16 feet wide. The additional area graded was 10,228 square yards and the additional area surfaced 5,337 square yards. The section was completed on September 4, 1912.

In the excavation 760 cubic yards of earth was moved, and the maximum cut was 1.3 feet and the maximum fill 2.7 feet. The maximum grade was reduced from 13.2 per cent to 4.4 per cent. The adjacent land is level and the soil is sandy. The earth was loosened with plows and hauled in drag, Fresno, and wheel scrapers for an average haul of 160 feet and a maximum haul of 350 feet.

The surfacing material consisted of a good quality of black gumbo and sharp, clean sand. The gumbo was spread to a depth of $7\frac{1}{2}$ inches and the sand to a depth of 6 inches, both measured loose. The two materials were mixed by means of plows and harrows and shaped with a steel drag and a road machine. The compacted depth of the finished surface was 8 inches and the crown was three-fourths inch to 1 foot. In this work 1,165 cubic yards of gumbo and 890 cubic yards of sand were used. The gumbo was hauled approximately 2 miles in flat-bottom dump wagons having a capacity of 1 cubic yard, and the sand was hauled 4,000 feet in the same wagons.

The outfit consisted of 4 drag scrapers, 2 Fresno scrapers, 1 wheel scraper, one 8-horse road machine, 1 steel road drag, 1 plow, 1 disk harrow, 1 spike harrow, and hand tools. Labor cost \$2 and teams \$4 per 10-hour day.

The total cost of the road to the community was \$1,663.15, which is at the rate of \$0.311 per square yard. The principal items of cost were as follows: Excavation, at \$0.158 per cubic yard, \$120; shaping the subgrade, at \$0.005 per square yard, \$28.20; loading gumbo, at \$0.155 per cubic yard, \$180.40; hauling gumbo, at \$0.60 per cubic yard, \$698.80; spreading gumbo, at \$0.029 per cubic yard, \$34; loading sand, at \$0.105 per cubic yard, \$93.60; hauling sand, at \$0.336 per cubic yard, \$299; spreading sand, at \$0.012 per cubic yard, \$10.60; mixing, at \$0.007 per square yard, \$37.20; rolling, at \$0.0025 per square yard, \$13.60; shaping, at \$0.001 per square yard, \$4; shoulders and ditches, \$46.40; purchase of gumbo pit, at \$125 per acre, \$41.35; miscellaneous, \$14; and superintendence, \$42.

SHELL ROADS.

FORT MYERS, FLA.—A shell road leading from Fort Myers toward Punta Rassa, known as the McGregor Boulevard, was begun on May 15, 1912, and completed on December 11, 1912. This road was constructed in two sections—one section lying within the corporate limits of Fort Myers and paid for by the municipality, and the other outside of the corporate limits and paid for by the county. The land adjacent to the road is approximately level and the soil is sandy throughout.

The town section (waterbound).—The town section was 7,200 feet long, and was graded to a width of 28 feet outside to outside of shoulders or 36 feet between curbs. The shell surface replaced an old surface of the same kind which had become badly worn, and extended the entire length of the section. It was 16 feet wide and the surfaced area was 12,800 square yards. The shell was spread 12 inches deep and compacted to 6 inches. The total amount of shell used was 3,838 cubic yards, all of which was purchased at a cost of \$1.0203 per cubic yard. Two hundred and five feet of vitrified clay culvert pipe, ranging in diameter from 15 inches to 24 inches, was used. A reinforced concrete girder bridge, having a span of 24 feet, a width of roadway of 24 feet, and a 6-foot height of opening, was constructed at station 59. This bridge was constructed by contract and cost \$1,540.

The total cost of the road, exclusive of the concrete bridge, was \$6,539.36, making a rate of \$0.511 per square yard. The cost of labor was \$1.50 per 10-hour day and of teams \$5 per day. The principal items of cost were: Clearing, fine grading, and trenching, \$579.60; scarifying the old road, \$115.50; culvert pipe delivered, \$183.70; labor for pipe culverts, \$70; surfacing material at dock, \$3,915.96; hauling the surfacing material from the dock to the road, \$1,186.35; spreading the surfacing material, \$334.25; and rolling, \$154. Wood for fuel for the roller was cut by county convict force and the cost is not included.

The equipment consisted of a 10-ton road roller, slat-bottom wagons, and hand tools. The average haul for shell was 1 mile and for water for the roller $\frac{1}{2}$ mile.

The county section (bituminous).—The county section was 9,100 feet long and had been partially graded before the object-lesson work was begun. The available cost data concerning grading were, therefore, not complete. The width graded was 24 feet and the width surfaced 16 feet, making a total area of 24,267 square yards graded and 16,178 square yards surfaced. The shell was spread to a depth of 14 inches in the center and 10 inches on the sides, and compacted to 7 inches in the center and 5 inches on the sides. The shell was old and rotten and ranged in size from whole oyster shells to small fragments.

After this material had been spread and partially compacted, a thin bituminous binder was applied to the surface cold, at the rate of one-half gallon per square yard, and left undisturbed until the next day. Shell fines and sand were then spread over the bitumen and the surface was rolled until thoroughly compacted. The length of road treated with bitumen was 8,950 feet and the area 15,911 square yards.

Vitrified clay pipe, 168 feet by 24 inches, half-round corrugated iron pipe, 56 feet by 60 inches, and circular corrugated pipe, 32 feet by 48 inches, were used in constructing culverts.

The equipment consisted of a 10-ton roller, a road grader, flat-bottom wagons of 2½ cubic yards' capacity, and hand tools, and labor cost \$1.50 per 10-hour day for men and \$5 for teams. The cost was distributed as follows: Clearing, grading, and ditching (estimated), \$1,800; wood for fuel for the roller, \$150; shaping the subgrade, 16,178 square yards, at \$0.00644 per square yard, \$104.25; culvert pipe, \$595.88; labor on the culverts, \$136.25; shell for surfacing, 5,608 cubic yards, at \$1.0125 per cubic yard, \$5,678.55; hauling the shell, 5,608 cubic yards, at \$0.446 per cubic yard, \$2,499.75; spreading the shell, 5,608 cubic yards, at \$0.0678 per cubic yard, \$380.25; sprinkling, 16,178 square yards, at \$0.00513 per square yard, \$83; rolling, 16,178 square yards, at \$0.01845 per square yard, \$298.50; trimming the shoulders and ditches (41,000 feet), \$175.75; bitumen, 8,089 gallons, at \$0.09 per gallon, \$728; demurrage on car, \$81; hauling the bitumen, \$68; spreading the bitumen, 15,911 square yards, at \$0.00613 per square yard, \$97.50; applying shell fines and sand, 15,911 square yards, at \$0.00778 per square yard, \$123.75; and incidentals, \$6.

The total cost of the road to the community was \$13,006.43, which is at the rate of \$0.804 per square yard.

ANNAPOLIS, MD.—Several sections of road aggregating approximately 7,052 feet in length upon the grounds of the United States Naval Academy at Annapolis were improved between April 17, 1913, and May 16, 1913. The land adjacent to these roads is nearly level and the soil has been made by filling with various materials, such as clay, brick, shells, etc. The maximum cut and the maximum fill were each about 0.5 foot, since the grading was essentially only a matter of correcting slight irregularities in the grade of the old roads. The cost of labor was \$1.28, and of 1-horse teams \$2 per 8-hour day.

The equipment consisted of one 4½-ton tandem roller, one 10-ton macadam roller, 1 spike-tooth harrow, 1 water wagon, one 2-horse grader, carts, picks, shovels, etc. The average haul for excavation was 1,000 feet and the maximum haul, 2,000 feet. The hauling was done in carts having about ½ cubic yard capacity. Shell for surfacing was brought by water for a distance of about 40 miles and hauled in 25-bushel carts 800 feet from the scow to the road. It was not necessary to provide any additional culverts or other drains on any part of the work.

The improvement consisted in shaping the old road, a considerable part of which had been previously surfaced with shell, and constructing a new oyster-shell surface. The wearing quality of the shell was apparently not very good. The surfacing was done in seven sections having the following dimensions. length by width: 878 feet by 18 feet, 854 feet by 20 feet, 430 feet by 18 feet, 2,000 feet by 18 feet, 740 feet by 26 feet, 1,500 feet by 18 feet, and 650 feet by 15 feet, and the total area surfaced amounted to 11,935 square yards. The depth to which the shell was spread varied from 2 inches to 13 inches, measured loose, according to the condition of the surface, and the compacted depth was about one-third the loose depth. Material to the extent of 1,037 cubic yards was moved in the excavation and 46,125 bushels of shells were used in surfacing. In all, 24,300 bushels of shells were delivered on the road at

\$0.035 per bushel, while the remaining 21,825 bushels cost \$0.045 delivered at the Naval Academy docks.

The total cost of the work, exclusive of depreciation and fuel for the roller, was \$2,803.11, making the cost per square yard \$0.19. The principal items of cost were as follows: Excavation, 1,037 cubic yards at \$0.30 per cubic yard, \$310.44; shaping the subgrade, \$236.76; surfacing material delivered on the road, 24,300 bushels, at \$0.035 per bushel, \$850.51; surfacing material delivered at the docks, 21,825 bushels, at \$0.045 per bushel, \$982.12; hauling the surface material, \$110.40; spreading the surfacing material, \$156.44; rolling the surface, \$155.16; and incidental expenses, \$1.28.

EARTH ROADS.

PANGBURN, ARK.—Work was begun on the River Road leading from Pangburn toward Cleburne County on September 2, 1912, and was completed on September 13, 1912. An earth road 1,000 feet long was constructed 30 feet wide.

The country is hilly and the natural soil from station 0 to station 8 is clay containing sandstone and shale. From station 8 to station 10, on the west side of the road, it is also clay and rock, but on the east side the soil is loam. There was no center cut and the maximum fill was 2 feet. The maximum grade remained 10 per cent, as it was before the improvement. The earth was loosened with a plow and picks, hauled in drag scrapers, and spread with shovels and a road grader. The presence of loose rock in the clay made excavation difficult. It was removed with picks and a bar by hand labor. The maximum haul was 120 feet and the average haul 40 feet. A retaining wall 27 feet long was built at station 8. It was made of the stone obtained in excavating and laid dry.

The equipment consisted of a road grader, a road plow, and hand tools, all of which were in poor condition. Labor cost \$0.125 per hour, and teams cost \$0.375 and \$0.25 per hour. The total cost of the road was \$166.75, which is at the rate of \$0.05 per square yard, or \$880.44 per mile. The principal items of cost were as follows: Clearing and grubbing, 3,333 square yards, at \$0.005 per square yard, \$17; earth excavation and embankment, 500 cubic yards, at \$0.18 per cubic yard, \$90; rock excavation, 42½ cubic yards, at \$1 per cubic yard, \$42.75; fine grading, 3,333 square yards, at \$0.0044 per square yard, \$14.50; and retaining wall, 5 cubic yards, at \$0.50 per cubic yard, \$2.50.

ZONA, FLA.—Work was begun on February 4, 1913, on a road leading eastward from the State canal, about one-half mile above Zona. The road was built between and parallel to two tributary ditches to this canal, which were about 40 feet apart, and the material excavated from the ditches was used in grading the road. The work was in the nature of an experiment, having for its object the development of a satisfactory road surface composed of the native black muck, muck and sand, or coralline rock. The road is in the Everglade district, and the material obtained from the ditches was of three distinct types. The top soil, to the depth of from 2 to 5 feet, was black muck, which is in reality decayed organic matter, finely honeycombed, very light and fluffy when dry, and very difficult to consolidate. Below this muck a layer of fine sand was encountered varying in depth from 1 to 3 feet. The formation below the sand was coralline rock.

The section of road improved was 6,800 feet long and 18 feet wide, making a total area of 13,600 square yards.

It was originally intended that the first 2,000 feet would be surfaced with coralline rock obtained from the banks of the State canal, and that the remaining distance should be divided into two experimental sections, the first to be surfaced with muck or loam, which was to be consolidated by a light tamping

roller, and the second to be surfaced with muck and sand spread in alternate layers and mixed by puddling with the tamping roller.

At the time the work was done labor and teams were difficult to obtain and no roller of any description was to be had. The specifications were drawn up, however, for a light tamping roller, and it was agreed by the interested parties to postpone the work until the roller could be made and labor and teams should become available. The work was accordingly discontinued on February 21, 1913, but it is hoped that it will be resumed and prosecuted at some future time when the conditions are more favorable.

The cost of the work done, which consisted in spreading the material from the ditch banks and shaping the road, was \$267.20, which is at the rate of \$0.019 per square yard. Labor cost \$2 per day and no teams were employed.

ORD, NEBR.—Work was started on an earth road running from Ord eastward toward Spelts on August 3, 1912, and finished on August 17, 1912. The land adjacent to the road is level, while the soil is loam with a quicksand subsoil from station 0 to station 30, and loam with a clay subsoil from station 30 to station 50—the end of the road. Earth to the amount of 2,462 cubic yards was moved, of which 180 cubic yards was loosened with a plow and hauled an average distance of 250 feet with Fresno and drag scrapers; 1,550 cubic yards was loosened and loaded with an elevating grader and hauled an average distance of 2,370 feet in flat-bottom wagons; and 732 cubic yards was placed with the elevating grader. The maximum cut was 0.6 foot and the maximum fill 1.6 feet. The maximum grade was reduced from 2 per cent to 1.6 per cent.

The road was graded 5,000 feet to a width of 24 feet, and the total area was 13,333 square yards. The crown of the roadway was three-fourths inch to 1 foot. Reinforced concrete culverts, 3 by 2 feet and 26 feet long, each containing 11.6 cubic yards of concrete and 600 pounds of steel, were constructed at stations 7+95 and 26+37, and a 12-inch vitrified clay-pipe culvert at station 33+80 was lengthened 6 feet and supplied with concrete end walls.

The equipment consisted of a 10-ton oil-burning tractor, an elevating grader, a road machine, drag and Fresno scrapers, flat-bottom wagons, and hand tools. The tractor, which was used for drawing the grader, consumed 270 gallons of petroleum. Labor cost \$2; teams, \$4; and foremen, \$4.50 per 10-hour day. Fuel oil cost \$0.095 per gallon; cement, \$1.84 per barrel; sand and gravel, \$0.50 per cubic yard; and steel, \$0.026 per pound.

The total cost of the road was \$743.88, which is at the rate of \$0.056 per square yard. The principal items of cost were: Grading, \$487.42; shaping the roadway, \$38.30; vitrified clay pipe (6 feet 12 inches), \$1.35; end walls, \$11.88; concrete culverts, \$203.93; and grading the road intersection, \$1. The costs of all materials are included above under the proper items.

CALYPSO, N. C.—On September 16 and 17, 1912, a representative of the Office of Public Roads who had supervised the construction of an object-lesson sand-clay road at Calypso, assisted the local road officials in getting work under way on an earth road. During these two days a section of road 800 feet long was partially cleared and graded, though no part of this was entirely finished.

Twenty-one dollars and twenty cents was spent for this work, of which \$6 was spent for clearing and grubbing and \$15.20 for grading. Instructions were given by the office representative for continuing the work.

MADISON, S. DAK.—An earth road leading southward from Madison toward Clarena, known as the Meridian Road, was begun on July 30, 1912, and a section 6,092 feet long was completed by August 6, 1912. The land adjacent to the road is rolling, and the soil is prairie loam with a clay subsoil. The maximum fill was 1.7 feet, and there was no cut. The maximum grade remained approxi-

mately 3.9 per cent, as it was before the improvement. Two corrugated metal culverts 26 feet long were constructed; one, 12 inches in diameter, at station 27+35 and one, 15 inches in diameter, at station 55+00.

The road was graded to a width of 44 feet, making a graded area of 29,783 square yards. Earth, 2,708 cubic yards of which was moved, was for the greater part placed with an elevating grader hauled by a gas tractor, though plows and scrapers were used when more practicable. After the rough grading was completed the road was harrowed with a disk harrow and then shaped and compacted with a blade grader hauled by the gas tractor.

The equipment consisted of 1 gas tractor, one 8-horse blade grader, 1 elevating grader, one 4-horse blade grader, 2 small wheel scrapers, 1 drag scraper, 1 plow, 1 disk harrow, 1 spike harrow, and hand tools. The gas tractor, with operator and supplies, was hired at a cost of \$25 per 10-hour day. Labor cost \$2.50 and teams \$4.50 per 10-hour day.

The total cost of the road to the community was \$236.92, or, disregarding the cost of culverts, \$182.80, which is at the rate of \$0.0061 per square yard. The principal items of cost were: Excavation, at \$0.0405 per cubic yard, \$109.82; fine grading, at \$0.0017 per square yard, \$50.48; compacting, at \$0.0008 per square yard, \$22.50; culvert pipe, \$49.92; and labor on culverts, \$4.20.

DICKSON, TENN.—Work was started on November 12, 1912, on an earth road leading southwest from Dickson and was discontinued on November 29, 1912, after a section 5,280 feet long had been graded to a width of 24 feet in cuts and 18 feet in fills. The adjacent land is hilly and the soil varies from loam to solid rock, with rock predominating. With the limited amount of funds available for this work, it was impossible to reduce the steep maximum grade of 10.1 per cent materially or to make the general character of the work such as was desired.

The total area graded was 11,710 square yards, while the volume of earth excavation was 1,700 cubic yards and the volume of rock excavation 25 cubic yards. The maximum cut was 3.6 feet and the maximum fill 2.5 feet. Earth was loosened with plows and hauled with drag scrapers and wagons or moved with a road machine. Rock was excavated by hand drilling and blasting with 40 per cent dynamite, and the loosened material was moved by hand. A 12-horsepower traction engine was used for plowing and also for pulling the road machine.

Two timber culverts were constructed—one at station 25+18 having a span of 2 feet, a height of opening of 1 foot 4 inches, and a length of 15 feet, and the other, at station 41+48, having a span of 3 feet, a height of opening of 2 feet, and a length of 24 feet.

The equipment consisted of one 12-horsepower traction engine, one 300-gallon tank, 2 plows, 2 No. 2 drag scrapers, 1 reversible road machine, and hand tools. The traction engine, road machine, and tank were hired as one outfit for \$9 per 10-hour day, and this price included all charges for operators, fuel, etc. Labor cost \$1.25 and teams \$3 per 10-hour day.

The total cost of the road to the community was \$429.65, which is at the rate of \$0.037 per square yard. The principal items of cost were: Clearing, \$1.13; excavation (earth), at \$0.194 per cubic yard, \$330.14; excavation (rock), at \$1.275 per cubic yard, \$31.88; dynamite for rock excavation, \$7.15; constructing culverts, \$4.30; materials for culverts, \$12.95; fine grading, \$12.60; superintendence, \$28; and incidentals, \$1.50.

FANNETT, TEX.—An earth road, leading from Fannett northwest toward Nome, was constructed between May 5, 1913, and June 13, 1913. The road traverses marsh or rice land, having a black, waxy soil. The maximum fill was 3 feet, and the average fill throughout the length of the road was 1 foot.

The maximum grade was 0.5 per cent. The material composing the embankment was loosened with plows, hauled with drag scrapers, and spread with a road grader. After the fill was brought to approximately 1 foot below grade with the local soil it was completed with a natural mixture of sand and loam which possesses fair binding and wearing qualities. The loam was hauled in ordinary farm wagons with slat bottoms for an average distance of three-eighths mile and spread with a road grader. The total length of the road constructed was 5,280 feet, and the width of the grade was 24 feet and of the loam surface 14 feet, making a total graded area of 14,080 square yards and a surfaced area of 8,213 square yards. The loam was spread to a depth of 16 inches loose and compacted to 12 inches. The crown of the finished roadway was approximately $1\frac{1}{4}$ inches to 1 foot. The material removed in grading amounted to 4,694 cubic yards, and 2,400 cubic yards of sandy loam was used in surfacing. In making the improvement it was necessary to raise two old wooden bridges to conform to the new grade. Labor cost \$1.75 and teams \$5 per 10-hour day.

The total cost of the road to the community was \$1,733.24, which is at the rate of \$0.211 per square yard of surfaced area. The principal items of cost were as follows: Excavation, 4,694 cubic yards, at \$0.171 per cubic yard, \$819.62; shaping the subgrade, 14,080 square yards, at \$0.0026 per square yard, \$36.75; clearing the right of way, \$7; raising the old bridges, \$17.50; loading sandy loam, 2,400 cubic yards, at \$0.107 per cubic yard, \$256.37; hauling the sandy loam, at \$0.235 per cubic yard, \$564.50; and spreading the sandy loam, at \$0.013 per cubic yard, \$31.50.

PALISCO, TEX.—Work was begun on the Turtle Bay Road leading northwest from Palacios on January 27, 1913, and discontinued on March 11, 1913, with the loss of 10 days on account of rain. It was originally intended that this road should be surfaced with mud-shell obtained from Matagorda Bay at the mouth of the Colorado River. After the road was graded and drained, however, for a total length of 14,900 feet, it was decided to postpone the surfacing until the spring of 1914. The land traversed by this road is approximately level, and the soil consists of sandy loam from station 0 to station 320, and gumbo throughout the remaining distance. Wooden culverts were constructed at stations 43+35, 51+30, and 59; and concrete culverts at stations 11+20, 18, 59+50, and 97. The road was graded 50 feet wide for approximately 4,600 feet and 45 feet for the remaining distance, making a total graded area of approximately 77,000 square yards. The total cost to the community of this road was \$2,554, which is at the rate of \$0.034 per square yard. Labor cost \$1.75, and teams \$4 for a 10-hour day.

It is anticipated that this work will be completed under the supervision of the Office of Public Roads, and that a detailed statement of costs will appear in a later report.

BAYFIELD, WIS.—A section of earth road was constructed in Bayfield County in the Redcliff Indian Reservation. This road leads north from Redcliff toward Sand River and is known as the Redcliff Road. The road improved is only a short section of what it was planned to improve. Plans were furnished for $3\frac{1}{2}$ miles of road, and this work has been pushed to completion during the past season by the local authorities. The work of grading was begun on June 10, 1913, and completed on June 13, 1913. The adjacent land is rolling and the soil is sandy loam from station 49 to station 51 and clay from station 51 to station 52+20. The section improved extends from station 49 to station 62+20 of the survey and is new location. The maximum cut was 3 feet and the maximum fill $3\frac{1}{2}$ feet. The maximum grade was 5 per cent and the minimum grade 2 per cent. Labor cost \$2 and teams \$5 per 10-hour day.

The equipment consisted of 1 road machine, 6 No. 1 drag scrapers, 2 plows, picks, shovels, etc. The only work done consisted in grading and shaping the road.

The total length graded was 1,320 feet. The width in cuts was 27 feet and in fills 24 feet. The total graded area was 3,960 square yards. The right of way was cleared to a width of 66 feet. The roadway was given a crown of three-quarters inch to 1 foot. In all, 745 cubic yards of earth was moved in the excavation and hauled an average distance of 75 feet, with a maximum haul of 300 feet. The total cost of the road to the community was \$238.50, which is at the rate of \$0.06 per square yard. The principal items of cost were: Excavation, 745 cubic yards at \$0.20, \$149; shaping with the road machine, 3,960 square yards at \$0.006 per square yard, \$24.50; and clearing and grubbing the right of way, \$65.

INSPECTION OF OBJECT-LESSON ROADS.

The arrangement adopted last year for providing for systematic inspection of work in progress and of projects submitted to this office by the local officials was so successful in saving time and expense that it will be continued.

A chief inspector has been appointed, and during the past year has reported as follows: Inspections of old object-lesson roads, 3; inspections of work in progress under field men, 14; and preliminary inspections of proposed work, 5. Special assignments of a confidential nature were covered at Raleigh, N. C., relative to the improvement of post roads in that State; at Elkhart, Ind., relative to county contract work in progress; and at Knoxville, Tenn., relative to the cost of macadam construction and a case at law involving contractors' anticipated profits. Special assignments were also covered at Letchworth Park, N. Y., in connection with the creation of a system of roads within the park limits; at Augusta, Me., for a study of the State highway system and a draft of a proposed State law establishing a highway commission, etc. Special advice and inspections of a routine nature were made at Anaconda, Mont., Nappanee, Ind., Gatesville, N. C., and Arcadia, Fla.

The chief inspector also made nine general inspections in connection with post-road projects under the Post Office appropriation act of August, 1912.

UNFINISHED WORK.

Object-lesson roads were begun at St. Johns, Ariz., Morgantown, N. C., and Appomattox, Va., during the latter part of the last fiscal year and are still in course of construction. These roads will be described in the report on the field work of the Office of Public Roads for 1913-14.

EXPERIMENTAL ROADS, 1912-13.

The office conducted a series of experiments in road building at the following places during the past fiscal year: Miami, Fla.; Chevy Chase, Md.; Rockville Pike, Montgomery County, Md.; and the Agricultural Department grounds, Washington, D. C. These will be described in greater detail in the regular annual progress report on experiments in dust preventives and road binders. A brief description of each road is, however, given below.

EXPERIMENTS AT MIAMI, FLA.

On June 9, 1913, at the request of the board of county commissioners of Dade County, Fla., an engineer was assigned from the Office of Public Roads to

supervise the construction of a series of test sections on the Biscayne Drive, about 2 miles north of Miami, for the purpose of investigating the practicability of a bituminous-surface treatment for the local roads. These roads have all been surfaced with a soft oolitic limestone, known locally as marl, coralline rock, or limestone, deposits of which are found in various sections of the county. Six separate experiments were made on as many sections of road, and the total area surfaced was 2,804 square yards.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.

The work at Chevy Chase is the continuation of the series of experiments begun in 1911, made possible through the appropriation by Congress of a special fund for carrying on such work. Various experiments in surface treatment were conducted on the section of water-bound macadam constructed in the past fiscal year.

In continuation of the 1911 experiments, additional sections were constructed upon a section of Connecticut Avenue, beginning at Bradley Lane and extending to the loop of the Capital Traction Co's. tracks at Chevy Chase Lake. The experiments are six in number, and comprise sections of bituminous concrete, concrete, oil-cement concrete, bituminous-surfaced concrete, surface treatments, and vitrified brick. Up to date about 16,378 square yards have been surfaced, as follows: Bituminous concrete, 2,898 square yards; concrete, 3,013 square yards; oil-cement concrete, 1,744 square yards; bituminous-surfaced concrete, 4,178 square yards; surface treatments, 2,490 square yards; and brick, 2,055 square yards.

In addition to the construction of these sections, the entire series of experiments was also systematically maintained.

EXPERIMENTAL WORK ON ROCKVILLE PIKE, MONTGOMERY CO., MD.

A part of the special fund appropriated for experiments in road improvement, together with funds furnished by the community, is being devoted to resurfacing the Rockville Pike in Montgomery County, Md. This road will be resurfaced with limestone macadam throughout its length and the surface will be treated with various bituminous materials in conjunction with gravel, trap-rock screenings, and limestone screenings. The experiments are being made to determine the best methods of maintaining macadam roads free from dust. During the past fiscal year about 26,675 square yards were surfaced with water-bound macadam.

EXPERIMENTS ON THE AGRICULTURAL DEPARTMENT GROUNDS, WASHINGTON, D. C

Several sections of driveway on the Agricultural Department grounds were given a surface treatment in October, 1912. This work was done on some of the same sections which have already been experimentally treated and described in former progress reports of the Office of Public Roads. A total of 4,485 square yards of surface was treated in 1912.

MEMPHIS-TO-BRISTOL HIGHWAY.

Work on the eastern division of the Memphis to Bristol Highway from Nashville to Bristol, which was started in January, 1912, was continued during the first part of the fiscal year 1912-13. The funds raised to defray the expenses of an engineer under an arrangement made with the office were exhausted in December, 1912, and connection with the work was severed.

Work was done in 10 counties—Cannon, Carter, Cumberland, Greene, Hamblen, Loudon, Roane, Warren, Washington, and White. On account of the badly sunken and worn condition of the existing roads together with the excessive grades, a new location was made on a large portion of the route, particularly on the section crossing the Cumberland Mountains, where the plans call for a new location throughout practically the entire distance of 55 miles.

All new location was made permanent, and it was frequently necessary to institute condemnation proceedings before the new right of way could be secured. The general maximum grade adopted was 5 per cent, but in one or two instances on the mountain sections it was necessary to use a 6 per cent grade on short stretches. Concrete or stone masonry was used in all the larger drainage structures, while corrugated metal or vitrified clay pipe was used for the smaller drainage areas.

Preliminary surveys were made on 159.2 miles and final location was established for 88.5 miles. On December 15, 1912, of the total unimproved mileage between Nashville and Bristol—152.3 miles—a total of 52 miles of grade and 17.4 miles of surfacing was finished, while uncompleted contracts and work being done by force account assured a total of 75.5 miles of finished grade and 52.1 miles of surfaced road. The status of the work on a percentage basis was: Unimproved mileage graded, 34.1 per cent; unimproved mileage surfaced, 11.5 per cent; unimproved mileage which will be graded upon completion of contracts, 49.6 per cent; unimproved mileage which will be surfaced upon completion of contracts, 34.2 per cent; and unimproved mileage remaining between Nashville and Bristol upon completion of contracts, 21.8 per cent.

The total quantities, together with the average unit costs, of the work done on the 52 miles of grade and 17.4 miles of surfacing finished were as follows: Clearing and grubbing 76.45 acres, at \$54.13 per acre; earth excavation, 225,513 cubic yards, at \$0.251 per cubic yard; loose-rock excavation, 306.8 cubic yards, at \$0.39 per cubic yard; solid-rock excavation, 15,215.9 cubic yards, at \$0.812 per cubic yard; overhaul on excavation, 44,446 yard stations, at \$0.01 per yard station; concrete, 686.1 cubic yards, at \$7.94 per cubic yard; masonry, 255.4 cubic yards, at \$6 per cubic yard; slag and gravel, 21,826 cubic yards, at \$0.634 per cubic yard; macadam, 18,332.5 cubic yards, at \$1.57 per cubic yard; 1,846 linear feet of 12-inch corrugated metal pipe, at \$0.74 per foot; 1,038 linear feet of 15-inch corrugated metal pipe, at \$0.90 per foot; 474 linear feet of 18-inch corrugated metal pipe, at \$1.02 per foot; 832 linear feet of 24-inch corrugated metal pipe, at \$1.48 per foot; 40 linear feet of 36-inch corrugated metal pipe, at \$2.99 per foot; 26 linear feet of 48-inch corrugated metal pipe, at \$4.29 per foot; 786 linear feet of 12-inch vitrified clay pipe, at \$0.58 per foot; 190 linear feet of 15-inch vitrified clay pipe, at \$0.78 per foot; 482 linear feet of 18-inch vitrified clay pipe, at \$0.97 per foot; 97½ linear feet of 20-inch vitrified clay pipe, at \$1.125 per foot; 764 linear feet of 24-inch vitrified clay pipe, at \$1.76 per foot; 39,054 pounds of steel I beams and rods, at \$0.045 per pound; 9,500 feet b. m. of bridge lumber, at \$35 per thousand; and crowning and shaping, 1,181,800 square yards, at \$0.01 per square yard.

The average earth excavation per mile was 4,326 cubic yards, and the average rock excavation per mile was 342 cubic yards.

The project was strictly a cooperative enterprise, and each county provided the funds necessary to build the section of road within its boundaries. In several counties the funds raised were not available during the year 1912 and no actual construction could be attempted. The progress of the work as a whole would undoubtedly have been much better if the funds in these counties had been available.

BRIDGE WORK, 1912-13.

The office constructed bridges at Drake, S. C., and at Cheraw, S. C. Descriptions are given below.

DRAKE, S. C.—A 25-foot span I-beam bridge with concrete floor, having a clear roadway 16 feet wide, was constructed at Drake. Work began on July 29, 1913, and the bridge was entirely finished by August 23, 1913. It was necessary to provide sluice gates in connection with this bridge, and the construction was on that account made more difficult than it otherwise would have been.

The abutments and wing walls contained 152.2 cubic yards of concrete, which was mixed in the proportion 1:3:6, while the floor slab and parapets contained 12.6 cubic yards of concrete mixed in the proportions 1:2:4. It was necessary to use 175 barrels of cement, 70 cubic yards of sand, 189.6 tons of gravel, nine 15-inch 42-pound I beams 28 feet long, 600 square feet of expanded metal, 56 linear feet of pipe railing, and 3,744 board feet of lumber. Convict labor and county-owned teams were used.

The total cost of the bridge, which includes the necessary convict camp expenses, was \$1,350.62. The principal items of cost were: Excavation, \$18; building forms, \$58.50; laying concrete, \$68.70; building sluice gates, \$10; placing I beams, \$5.40; removing forms and back filling, \$12.30; 175 barrels of cement, at \$1.70 per barrel, \$297.50; 189.6 tons of gravel, at \$1.45 per ton, \$274.92; nine 15-inch 42-pound I beams, at \$42.04 per beam, \$378.36; 600 square feet of expanded metal, at \$0.044 per square foot, \$26.40; paint for I beams, \$3.50; 56 linear feet of pipe railing, at \$0.73 per foot, \$40.88; 3,744 board feet of timber, at \$15 per thousand, \$56.16; hauling gravel, \$45; hauling sand, \$50; and hauling lumber, \$5.

CHERAW, S. C.—At Cheraw, S. C., a concrete bridge, which had been badly damaged, was repaired under the supervision of the office. The repair work began on August 27, 1913, and was finished on September 14, 1913. The total cost of the work was \$225.40, and the principal items of cost were: Hauling the materials, \$57; building dams and pumping water, \$27.75; work on the forms, \$8; mixing and placing the concrete, \$41.25; 924 feet board measure of lumber, at \$15 per thousand, \$13.86; 102 sacks of cement, at \$4.47 per sack, \$47.94; and wheelbarrows, drills, bolts, buckets, nails, etc., \$29.60.

PREPARATION OF PLANS.

Typical designs were prepared during the past fiscal year for concrete bridges and culverts ranging in span from 2 feet to 16 feet and for steel bridges ranging in span from 30 feet to 150 feet. About 350 blue-print copies have already been furnished from these plans for use at specific points. Special designs, prepared to cover cases for which the typical designs could not be used, were distributed by States as follows: Arizona, 1; Florida, 1; Iowa, 3; Kentucky, 7; Maryland, 4; Mississippi, 6; Nebraska, 2; North Dakota, 1; South Carolina, 2; Virginia, 1; and Wisconsin, 1.

BRIDGE INSPECTIONS.

Thirty-five separate inspections were made during the fiscal year 1912-13 in connection with which the local officials were given advice as to the most practical types of bridges for the various locations in question and as to the advantages to be derived from employing competent engineering supervision for all bridge work. These inspections were distributed by States as follows: Arizona, 1; Arkansas, 1; Iowa, 10; Kentucky, 9; Maryland, 3; Mississippi, 3; North Carolina, 4; South Carolina, 2; Virginia, 1; and Wisconsin, 1.



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Contribution from the Bureau of Soils, Milton Whitney, Chief.

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(PROFESSIONAL PAPER.)

THE TOPOGRAPHIC FEATURES OF THE DESERT BASINS OF THE UNITED STATES WITH REFERENCE TO THE POSSIBLE OCCURRENCE OF POTASH.¹

By E. E. FREE, *Scientist in Fertilizer Investigations.*

INTRODUCTION.

In essence the "desert basin" or "dry lake" potash theory is very simple and rests upon three propositions:

(1) Rocks and soils give up various salts, including those of potassium, to drainage waters which flow over them.

(2) In areas of inclosed drainage these salts, still including those of potassium, are concentrated wherever the waters evaporate.

(3) In this concentration the salts of potassium *may* have been sufficiently segregated from other salts to form a workable deposit.

It has long been known that a considerable section of the United States is undrained and apparently contains regions satisfying the conditions requisite to potash² concentration. The problem set the writer, early in the present Governmental investigation into possible potash resources, was the study of all of these undrained areas, or "desert basins," in the effort to determine which of them, if any, might possibly contain potash deposits, and which could reasonably be considered the more favorable from this point of view. The problem is a complex one and includes at least three distinct and different questions: (1) The question of accumulation; or of source, concentration and retention; (2) the question of segregation of the potash from the other salts; and (3) the question of the accessibility

¹ Manuscript prepared July, 1912.

² Throughout this bulletin the word "potash" is used in accordance with common usage, to signify any ordinary soluble compound of the element potassium.

NOTE.—This paper describes a topographical examination which has been made of the desert basins of the United States, with a view to the possible discovery of potash in commercial quantities, and is intended particularly for those interested in the production of fertilizers.

of the deposit if any exists. It can not be said that any one of these questions is more important than the others, since the solution of all will be essential to a full understanding of the greater problem. It is fair to say, however, that the question first named must first be solved. It takes precedence, perhaps, not logically, but chronologically. It is obviously useless to spend time in study of the conditions which may have controlled segregation in a basin to which no potash has been supplied or from which it has escaped.

The problem, then, is first of all that of locating those areas in which potash reasonably may be expected to have accumulated and from which it apparently has not been withdrawn. This is not a matter of simple observation. There are only very few of the basins in which deposits of soluble salts are exposed on the surface and may be examined directly. Nearly everywhere the salt bodies indicated on substantial though theoretical grounds have been more or less deeply buried by later deposits. Their character, even their presence or absence, must be inferred from general geological evidences, apparently somewhat remote from the point at issue.

Direct evidence being thus lacking and not easily obtainable, the first question (that of accumulation) becomes essentially one of topography and of areal geology. It is reasonable to expect that potash will have accumulated in largest quantity in that place where the greatest drainage has been concentrated for the longest time and where the rocks from which that drainage is derived are such as may reasonably be expected to yield potash most largely, easily, and rapidly. The matter may be reduced to three formal criteria: (1) The drainage area of the basin (past as well as present); (2) the existence or possibility of a present or past overflow (which might have removed the potash); (3) the nature of the rocks and soils exposed to the drainage.

Of these criteria the first two are the most important and both are essentially topographic. It is seldom that the rocks of an area are either entirely potash bearing or entirely the reverse. The study of the areal geology is not only seldom conclusive, but is always laborious and is obviously never necessary unless topographic conditions are known to be favorable. The first step of the inquiry is, therefore, the study of the topography of the undrained regions, and it is this step only which is taken in the present report. The writer here sets out to answer the question "In what basins has potash probably accumulated and been retained in significant amount?" With the no less important matters of segregation and position (especially depth) he is not here concerned.

The topographic data upon which the report is based have been gathered from many and various sources. Chief and most important are the topographic sheets of the United States Geological Survey,

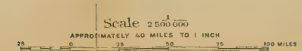






Mapped by
Edward E. Free
1912

BASE MAP IS A SECTION FROM
U.S. GEOLOGICAL SURVEY MAP
OF THE UNITED STATES



LEGEND
Pre-Lahontan Divides ———
Post-Lahontan Divides Internal ———
Post-Lahontan Divides From Sea - - - - -

and where these were available other data have seldom been sought. For areas as yet unsurveyed by the Geological Survey, use has been made of the maps of the Wheeler and King surveys, of the maps and notes of the General Land Office surveys, of railway surveys and profiles, of various special maps and reports published by the Geological Survey and by the early Government surveys, of the maps and journals of the early explorers, of many private maps, both published and unpublished, of maps and articles in the technical press, etc. These data have been supplemented by about 25,000 miles of personal travel through the regions in question and by conference with official and private surveyors, railway engineers, prospectors, and others familiar with the country. It is impossible to acknowledge all these sources in detail, but the writer wishes to make special acknowledgment of the kindness of Prof. G. E. Bailey, of Los Angeles, in tendering the use of his collection of personal maps and notes of the desert basins of California, as well as in communicating the various conclusions resulting from his extensive travel in these regions.

The topographic data from all the sources mentioned have been collected, carefully compared, and the final conclusions used in platting on base maps the boundaries of the various basins. From these maps have been calculated the areas given in the following pages. Every possible care has been used in the platting of the lines and in the computation of the areas, and it is believed that accidental errors have been almost if not quite eliminated. In nearly all cases the areas as given may be considered accurate within 10 per cent and in most the accuracy is far greater. In a few places, mainly in country of slight relief and where divides are inconspicuous, the position of present and past water partings remains uncertain, and the areas are correspondingly open to doubt. All such cases are noted in detail in the text and, in general, a perusal of the text will indicate the probable accuracy and assurance of the various conclusions better than could be done by any general statement.

THE GREAT BASIN AND ITS DEVELOPMENT.

The most important areas of internal drainage in the United States lie within the so-called "Great Basin" of Utah, Nevada, and California. This is by no means a unit, but an area of somewhat complex topography divided into a number of basins of various ages and characters. In order that this topography may be the better understood it is necessary to discuss briefly the history of its development, and this is perhaps the more useful since its development has been in many ways parallel to that of other undrained areas which lie beyond its borders. There is scarcely a phase of basin topography elsewhere that has not its counterpart in the Great Basin.

In Paleozoic and Pre-Cambrian time the area which is now the Great Basin was alternately above and below the sea, finally attaining in late Carboniferous time an emergence which was to be permanent. Its Triassic and Jurassic history is recorded only in fragments. Apparently it was largely and more or less continuously above the sea and was probably eroded to a low and mature relief. With the end of the Jurassic came the birth of the Sierra Nevada and with it the movements by which the basin was first outlined. The forces and the yielding of which the nascent Sierra were the expression did not spend themselves in this alone, but extended far to the east. At first by folding, later by profound and complex faulting, the former region of inconspicuous relief was broken into a series of troughs and ranges limited on the east by the westward-facing scarp of the Wasatch, as on the west by the Sierra. The more prominent lines of fracture being north and south, and the accompanying crustal displacement mainly by monoclinal tilting, there originated the series of north-and-south trough valleys and of parallel, monoclinal ranges so characteristic of the Great Basin.

Extensive faulting is likely to be pictured as cataclysmic, and one is tempted to think of the Great Basin as breaking in a day, like a dropped platter, from its original unity into the hundreds of structural fragments that now compose it. This is radically wrong. The present structure of the basin has grown very gradually. The movement initiated at the close of the Jurassic has continued ever since and is still in progress. So slow, indeed, has been the development of the relief that many streams have been able to maintain what seem to be their Jurassic channels and have cut the rising ranges as fast as they arose. This did not always happen, and sometimes the streams were turned. It would seem that different displacements were of different ages and have grown with differing rapidities.

Neither must it be imagined that the structure is completely simple and regular. The general parallelism of valleys and ranges is quite unmistakable, but details are much more complex. Ranges sink and bend and merge with other ranges; valleys join to other valleys and are cut by transverse uplifts; all to make a structure of extreme complexity, but through which the original simplicity may still be discerned.

It is impossible to say just when in this slow structural development the region became a "basin;" probably not for a long time after the structure had begun to take form. The whole of the Cretaceous and the early part of the Tertiary seems to have been a period of open seaward drainage and energetic erosion—an erosion which has severely modified many of the ranges. In the early Tertiary this erosional period was closed (though not necessarily with causal relation) by a period of intense and long-continued vulcanism which is only now

drawing to a close and which was marked by extensive and repeated flows of rhyolites and basalts, and by the discharge of enormous quantities of fragmental material. This period was characterized by the existence of a number of scattered and successive lakes, often quite extensive but probably shallow, in which the fragmentary volcanic material found a resting place. Apparently the region was then cut off partially or completely from the sea, and while most of these lakes probably overflowed, the occurrence of salt and gypsum among their deposits indicates that some of them were saline.

The division between this Tertiary period and the present is not a sharp one. With the lapse of time vulcanism has decreased, movement has disturbed the Tertiary lake beds, and erosion has doubtless been active; but conditions are essentially the same now as then and the Tertiary lakes find their direct descendants in the present "dry lakes" or playas and in the great lakes of the recent past.

In summary, the history of the Great Basin region begins at the close of the Jurassic with crustal movements which have continued ever since. At first these movements did not interfere with seaward drainage or normal erosion, but early in the Tertiary the separation from the sea began to be effective and the "Great Basin" (perhaps then drained by overflow) was produced. Since that time rising walls and increasing aridity have joined hands to make the imprisonment of the drainage more effective.

So much for the general outline of the history. It is now necessary to examine its most recent section a little more closely. In a time which is usually correlated with the Glacial Epoch many of the inclosed valleys of the Great Basin contained large and persistent lakes. The beginnings, the early history, even the exact chronology of the lakes remain unknown. They were probably preceded by a period of aridity and they probably rose very slowly. All this is yet uncertain and need not be pursued. Starting with these lakes, we find that they were subject to extreme variations of level, probably in response to the climatic fluctuations, now coming to be recognized as both incessant and world-wide.¹ These fluctuations are not yet worked out in detail, but they seem to indicate two main periods of lake expansion separated by a long period of contraction, probably to complete desiccation. The second expansion was followed by a second desiccation and contraction to the present condition. Since the beginning of this double-lake period the structural movements, though continuing, have been slight and have not affected the topography.

The detailed history of this lake period—its precedent conditions, its chronology, its various physiographic and chemical relicts—is

¹ See the books and papers of Ellsworth Huntington, especially the *Pulse of Asia* (1907) and *Palestine and its Transformation* (1910).

among the most interesting of present-day geologic problems, but it can not be pursued here. It will suffice to note briefly a few of the effects of it and the preceding history upon the topography, and especially upon the formation of inclosed basins. In the long period during which the Great Basin has been cut off from the sea the erosional waste of its mountains has been accumulating in its valleys until all are now filled very deeply with such alluvial *débris*. The character of all is the same. Where the mountain reaches the plain it is surrounded by a broad alluvial slope or "apron," which stretches outward with ever-decreasing slope until it merges with the apron of another mountain or into the practically level plain which forms the deepest depression of most of the valleys. This plain may carry a tiny lake, but more commonly it has only a clay flat or "playa," on which waters gather in wet weather or after storms, but which is usually dry. This succession of mountain slope, apron, gradually flattening plain, and playa is typical of all the desert basins. The playa is the place of concentration of all the present drainage and the playa is usually more or less saline, depending upon the amount and character of this drainage and the time during which it has been received.

The alluvial filling of the valleys is not of itself of much importance to this inquiry, but one phase of it is very much so. Where canyons cut back into a mountain range the discharge of detritus is more concentrated and the normal apron grows into an alluvial cone or fan which may extend many miles into the valley. If two mountain ranges face each other across a trough-like valley (as they usually do in this region), and if a canyon in one range chances to discharge opposite a canyon in the other, the fans which they build may ultimately merge in the center of the valley and gradually build a ridge or dam which rises few or many feet above the general valley level. By this process of "alluvial damming" a valley trough may be cut off at one end or both, or split into sections by dams composed entirely of alluvial mountain waste. Obviously this is possible only where the climate is arid. If the rainfall and run-off are sufficient to maintain a vigorous through-flowing stream the fans can not merge. The detritus will be carried entirely out of the valley, or graded to slopes which permit free egress of the waters. But it is probable that the Great Basin and its environs have been essentially arid ever since the early Tertiary and the processes of fan-building and fan-merging have been everywhere at work. Many valleys structurally open to the sea have been dammed in this way and many of the basins whose major limits are structurally defined have been divided by one or many of these alluvial dams.

Some of the alluvial dams are very ancient, some are very recent. The period of lake expansion was, of course, a period of vigorous

streams, and it is probable that few new alluvial dams were formed. But with the advancing aridity which has caused the disappearance of the lakes many valleys once freely open have been barred by alluvial dams and converted into areas of inclosed drainage. Obviously this has great importance from the present viewpoint. A valley where inclosed drainage is a condition of recent origin can not reasonably be expected to have retained important quantities of salts. In cases, therefore, where the boundaries of valleys are alluvial dams it is necessary to determine so far as may be possible the age of the dams, and whether they are sufficiently old and permanent to have retained behind them the more plentiful waters of the lake period.

The building of alluvial dams has been accompanied by another basin-creating process—the decay of the drainage systems due to an excess of evaporation over rainfall and the consequent failure of streams to maintain themselves over their whole length. In this way local depressions in the valleys become cut-off lakes, and channels or flood-plains become alkaline flats, even without the formation of important alluvial dams. Very much of the West is not so much an area of inclosed drainage as one of no drainage, but thousands of dry stream beds furrow its surface and scores of greater channels bear witness to a time when rivers were not all of sand. Occasional floods may fill these channels for a day; there may be still some constant drainage through them as underflow, but essentially they are dead and the alkali flats which dot their courses mark the places of their burial.

Alluvial damming and stream decay mean two things; first that many new and recent basins have been produced, and second, that a large part of the drainage and salt supply of the earlier basins has been cut off; for these processes have been just as active in the regions tributary to the greater basins as in regions once tributary to the sea, and the areas from which salt and water now reach those basins are often but a small fraction of what was once their compass. This, however, is not a matter of great importance. The answer to it is the same as to the statement—frequently made as an objection to the general potash theory—that the desert basins are too arid for the occurrence of rock decay and the freeing of potash. The basins were not always so arid. The lake period was one of considerable humidity, and we may be sure that during it plenty of potash was freed and carried to the central sinks. The doubt is not whether there is any potash, but where it is and whether it has been sufficiently segregated.

There remains to notice one more aspect of the history of the region. It has already been noted that extensive salt deposits are very rare on the surfaces of the present basins. In many of the

basins no salts at all are visible. There can be no reasonable doubt that large amounts of salts have entered these basins and remained there. Where are they now? To meet this dilemma Gilbert and Russell devised the theory of salt burial and of "freshening by desiccation." Essentially this theory says that when a body of salt is left behind by a desiccated lake on a playa or its topographic equivalent, this salt body may ultimately be covered by inwashed clay and sand without solution, and if a second lake comes later to occupy the basin the buried salt deposit will be protected by its alluvial seal and will remain undissolved. Certain stages of this process have actually been observed, and there is little doubt of the essential correctness of the theory or of its applicability to the present problem. We can assume quite safely that the salt which must have been in the great Quaternary lakes is now buried beneath the floors of their basins.

There arises at once the question of the horizon at which these salts are to be found, and the duplicity of the lake period seems to furnish at least a suggestion along this line. Periods of lake expansion and stream vigor are periods of salt accumulation. It should be concentrated and deposited when the lakes evaporate. There are, therefore, at least two horizons at which salt deposits are to be looked for: (1) That corresponding to the drying of the first great lake (the "interlake arid period") and (2) that corresponding to the drying of the second great lake; that is, the arid period of the present and the recent past. The few surface salt deposits known in the desert basins are believed to belong (with perhaps one exception) to this second period of accumulation. The "interlake" salt—probably far larger in amount—is believed to be everywhere more or less deeply underground.

The various undrained areas outside the Great Basin have had their own structural histories, sometimes analogous to that of the basin but more often not. Where necessary these structural histories will be noted briefly in the detailed chapter which follows. The climatic history, however, has been everywhere the same. In particular the processes of alluvial damming and of stream decay have been as active outside the Great Basin as within it, and indeed most of the undrained areas external thereto have originated in this way. The contraction and mutilation of the great drainage systems have left tremendous areas now without seaward drainage and split into inclosed basins of larger or smaller area. The following chapter will furnish numerous illustrations.

A brief word as to nomenclature is perhaps necessary. The double period of lake expansion has been variously referred to as "Quaternary," "Pleistocene," "Glacial," etc. All of these terms carry suggestions of chronology and correlation, the discussion of which

is beyond the scope of the present report, and which it is desired to avoid. It is thought best, therefore, to designate this period simply by the name of the great lake which best illustrates its history, and to refer to it as the Lahontan period. This is meant to include the whole period of deciphered lake history from the initial rise to the end of the second or final desiccation. No implication is intended as to the internal character of this period, and no specific names are applied to its various divisions.

THE UNDRAINED AREAS OF THE UNITED STATES.

It has already been noted that the Great Basin is not a unit. Its parallel mountain ranges cut it into numerous more or less connected valleys, and about halfway across the basin from east to west is one range in particular—the White Pine-Ruby Range—which has formed a major parting of the waters of the basin. East of this range is the Bonneville Basin, whose deepest depression was occupied by the ancient lake of that name and whose valleys now drain to its remnant—the Great Salt Lake of Utah. West of the range the Humboldt River cuts across the northern ends of the north-south ranges and discharges into the Carson Sink, once the home of the ancient Lake Lahontan. The basin of this lake then included not only the drainage of the Humboldt River, but also that of the Carson, Truckee, and Walker Rivers, the two latter of which have since been cut off by desiccation. These, with various smaller basins tributary to the early lake, form the Lahontan Basin.

North of the whole of the Great Basin and south of the eastern or Bonneville section of it the ranges and trough valleys which characterize it merge into wide, dissected plateaus, that of the Columbia and Snake River lavas on the north and that of the Colorado Plateau on the south. The southern limit of Lahontan is very different. The great trough valleys which characterize the core of the Great Basin are diverse in their slope, some draining northward and some southward. Most often, however, they drain both ways from an alluvial divide somewhere near the center. Thus the troughs forming the eastern part of the Lahontan Basin drain into the Humboldt River from their northern portions, while their southern extremities slope and drain either toward smaller basins also inclosed or toward some tributary of the Colorado River. Farther to the west the southern boundary of Lahontan is a transitional area of irregular cross uplift in which are a number of small basins, conveniently grouped with those of the Nevada trough valleys that chance to be inclosed. West and southwest of these is the great trough system of California, containing the Owens, Searles, and Panamint Valleys and their smaller analogues, and the great basin of Death Valley, to which

belong the present and former drainage systems of the Amargosa and Mojave Rivers.

The Great Basin contains but one other major division. Northwest of the Lahontan Basin, where the zone of uplift and fracture extended into the great lava plateau of eastern Oregon and northeastern California, a number of small basins were produced. Some of these drain or have drained to Lahontan, some to the sea, and some have been permanently inclosed.

Outside the Great Basin there is but one inclosed area where structure appears to have controlled the restriction of the drainage. This is the great trough between the Sacramento and San Andreas uplifts in central New Mexico, and extending southeastward into western Texas. Even here the structural character of the basin is far from certain, as will appear when the region is discussed. The only other large and well-known basin is the Salton, in southern California. It, too, occupies a structural trough which is, however, open to the sea, the only barrier being an alluvial dam apparently built by the Colorado River.

Though the above statements cover all important structural basins and all which have attracted any considerable attention, there remain numerous and extensive areas where seaward drainage has ceased because of the decay and contraction of the river systems. These areas are of considerable diversity, but fall well into geographical groups and will be so discussed.

In the detailed discussion which follows all undrained basins of the United States will be treated under the following groups:

- (1) The Lahontan Basin and its tributaries.
- (2) The Bonneville Basin and its tributaries.
- (3) The basins of the Lava Plateau.
- (4) The trough valleys of Nevada and the basins of the Transition Zone.
- (5) The trough valleys of California and the Mojave Desert.
- (6) The Salton Basin.
- (7) The basins of the New Mexico-Texas trough.
- (8) The trough valleys of Arizona and Sonora.
- (9) The Lordsburg-Membres region (New Mexico) and the Chihuahua bolsons.
- (10) The Rocky Mountain basins.
- (11) The Great Valley of California.
- (12) The filled lakes of the California ranges.
- (13) The basins and ponds of the Colorado Plateau.
- (14) The ponds and coulées of Eastern Washington.
- (15) The ponds of the Great Plains.
- (16) Local basins of unusual origin.

This classification, while setting out to be both genetic and geographic, has ended by being scarcely more than arbitrary, but this seems not to be remedied, and it is hoped that the index and the key map will help to cover the lack of a more logical arrangement. Each basin or group of basins has been given a name by which it is known throughout the report and which is, wherever possible, the name by which it is known to residents of the neighborhood or in former geologic studies. These names are given on the accompanying map, in the index, and in the synoptic list of Table I (p. 60) and will enable the ready location of information concerning any basin or region.

THE LAHONTAN BASIN AND ITS TRIBUTARIES.

At the present time the Lahontan Basin contains internal divisions, structural and alluvial, dividing it into a number of separate basins of which the major are the Black Rock Basin, the Humboldt-Carson Basin, the Truckee or Pyramid Lake Basin, and the Walker Basin. The studies of Russell ¹ have shown that the water of Lake Lahontan rose sufficiently to unite all of these basins into one water body. At the highest stages of the lake the present Humboldt-Carson Basin was connected with the Walker through the pass south of old Fort Churchill, with the Truckee through the Ragtown Pass and the pass at Wadsworth, and with the Black Rock through the pass north of Humboldt Station on the Southern Pacific Railway, the latter basin being also connected with the Truckee at the north end of the present Pyramid Lake. Both the Black Rock and the Truckee Basins were connected with the smaller Honey Lake Basin through passes at the northwest corner of the present Pyramid Lake. At this time the drainage area of the Humboldt River was much greater than at present, a large part of it having since been cut off by alluvial damming. The areas tributary to the Truckee and Walker Rivers were also slightly larger than now. The Carson was practically the same.

As the waters of the lake went down the first divide to appear was probably that between the Humboldt-Carson and the Allan Springs Basin, a small tributary to the south. Next the Walker became a separate basin, though perhaps continuing to overflow into the Humboldt-Carson. At about the same stage the direct connection between the Humboldt-Carson and the Black Rock was broken, though there still remained the indirect connection through the Truckee. A hundred feet additional lowering saw the appearance of the divide at Wadsworth between the Humboldt-Carson and the Truckee and the separation of the original lake into three water bodies—the Black Rock, Honey Lake, and Truckee

¹ U. S. Geological Survey, Monog. XI (1885).

body to the north, the Humboldt-Carson in the center, and the Walker to the south. The divide between the Truckee and the Black Rock was the last of the greater divides to appear, and with its emergence the basin assumed its present major divisions. The total area tributary to Lake Lahontan during the period of greatest expansion was 45,730 square miles. The investigations of Russell have shown conclusively that the lake never overflowed, and consequently all the salts received from this tremendous area must be still within it. There follows a brief description of the topography of the present divisions of the basin.

THE BLACK ROCK BASIN.

The present Black Rock Basin occupies an area of 8,550 square miles, mainly in Nevada, but with extensions into Oregon and California. Its sink, the Black Rock Desert, lies in the great filled trough east and southeast of the Black Rock Mountains, and, with its extensions southwestward in the Granite Creek, Smoke Creek, and Mud Lake Deserts, covers an area of over 1,030 square miles. The main present tributary is the Quinn River, which enters the Black Rock Desert at its northern extremity. Though the waters of the Quinn River still reach the sink at high-water periods, the stream now possesses scarcely a tithe of its former vigor, and its channel is much choked with débris and contains many alkali flats caused by local evaporation. Other streams which lead toward the sink are either dry except for occasional floods, or lose themselves immediately on entering the playa. Like other playas, the Black Rock Desert is not exactly level, but in the absence of accurate surveys the position of its lowest sink is not determinable. Probably it contains several local depressions each a few feet below the general surface and each separated from its neighbors by gentle slopes and invisible divides. After seasons of heavy snow and rainfall, shallow bodies of water sometimes stand for several weeks in certain portions of the playa, and these are probably among the areas of greatest depression.

From the mountainous country west of the Black Rock Mountains the basin receives the overflow of High Rock Lake, with a drainage area of 670 square miles, and of Summit Lake, which drains about 40 square miles. Water supply to both these lakes is now so far reduced that their overflow, if any, seldom reaches the desert, but essentially they still drain thereto and their drainage areas are included in the area given above.

During the higher stages of Lahontan the Black Rock section of the lake was connected with or received the drainage from the Kumiva, Granite Springs, Hot Springs, and Jungo Basins. Including these, its Quaternary drainage area (including the area covered by the lake) was 10,500 square miles. The Honey Lake Basin, though long connected with the Black Rock, is discussed as a separate unit and is not included in the area given above.

THE KUMIVA BASIN.

The Kumiva Basin lies in the small trough east of Kumiva Peak and separated by low alluvial divides from both the Black Rock Desert and the Granite Spring Basin, next to be described. The age of these divides is uncertain, but both were covered by the waters of Lake Lahontan. The divide into the Black Rock Desert is a little the lower, and it is probable that when the Lahontan waters were subsiding the drainage out of the Kumiva Basin was in this direction. Indeed, it is quite probable that this divide is recent and was formed by post-Lahontan alluviation. The lowest depression of the Kumiva Basin contains a playa about 10 square miles in area, but

because of the recency of outward drainage it is not to be expected that this playa or the basin will contain any considerable amount of salt. The area of the present basin is 445 square miles.

THE GRANITE SPRING BASIN.

The Granite Spring Basin is essentially similar to the Kumiva, and is similarly barred from the Black Rock Desert by a low alluvial divide which was overtopped by Lake Lahontan. This divide is higher than that which limits the Kumiva Basin, and probably it is more ancient, but the previous connection with Lahontan destroys any possibility of important salt concentration. The area of the present basin is 890 square miles. Its lowest depression is occupied by a playa of usual character, covering about 30 square miles.

THE JUNGO BASIN.

The Jungo Basin is a small depression in the strait which once connected the Black Rock and Humboldt-Carson water bodies north of Humboldt Station. At present the basin is separated from the Humboldt Valley by an alluvial divide west of the Eugene Mountains and from the Black Rock Basin by a similar and inconspicuous divide on an approximately east-west line passing through the Dunisher Hills. This second divide is the lower and the Jungo Basin probably retained connection with the Black Rock Basin some time after its connection with the Humboldt-Carson was broken. Indeed, this northern divide, though now about 125 feet above the bottom of the basin, has probably been considerably raised by recent alluviation and perhaps also by dune movement, and it is by no means certain that the divide existed in Lahontan time. At any rate, there was connection with the larger lake body over the divide and any great retention of salt in the Jungo is not to be expected. The present basin area is 340 square miles, and the typical playa which occupies its lowest depression covers about 5 square miles.

THE HOT SPRINGS BASIN.

West of the Granite Creek Desert and just north of Granite Peak there is a small pocket in the mountains into which extends an arm of the Black Rock playa. This arm is now cut off from the main desert by a low and recent divide and contains an "alkali" flat which owes its salinity mainly to the evaporation of the waters of several hot springs rising within and around it. Its saline accumulations are probably very superficial and of no importance. The drainage area is 270 square miles and the area of the alkali flat about 10 square miles.

THE HONEY LAKE BASIN.

The depression which forms the Honey Lake Basin has perhaps closer topographic affiliations with the basins of the lava plateau region than with the Lahontan group, but, chancing to have a low pass opening eastward, it was filled by an arm of the great lake during most of the lake's existence. The direction of water movement between the two bodies is not fully certain, but that matter is beyond the scope of the present report. The present basin has an area of 2,660 square miles, in which is included the tributary basin of Eagle Lake. The waters of this lake do not now reach the central basin, but they did so very recently. The main present tributaries are the Susan River from the west and Long Valley Creek from the south. The bottom of the basin is an extensive playa diversified by some vegetation and a number of old dune areas. In the deepest depression of this playa is the present Honey Lake, a shallow body of slightly brackish water and very variable in size. East of the lake the playa stretches out in a broad area known as Flannigan Flat, nearly level and with few visible drainage lines. Many portions of this flat are now alkaline from local drainage concentration, but the salinity has been

recently acquired and is unimportant. Little salt is now visible in the Honey Lake Basin.

On the northwest slope of Peavine Peak there is a small basin about 30 square miles in area which contains a small marsh separated from the headwaters of Long Valley Creek only by a low alluvial divide near the station of Purdy, on the Nevada, California & Oregon Railway. During Quaternary time this small basin undoubtedly drained into Long Valley Creek, and it has therefore no importance to the present inquiry. Its area is included in the above figures for the Honey Lake Basin.

THE TRUCKEE BASIN.

The Truckee Basin consisted in Quaternary time, as it does now, of the drainage basin of the Truckee River heading in the Sierras, notably in Lake Tahoe, and emptying into the twin lakes Pyramid and Winnemucca. The approach of the river to these lakes is over somewhat dissected alluvium, and the river has flowed at times into the one lake and at times into the other. At the present time it flows into the Pyramid. During the existence of Lake Lahontan the valley of Winnemucca Lake contained a long, narrow arm of water connected with the Pyramid Lake body at its southern extremity, while the northern end of the latter lake joined the water body of the Black Rock Desert. This latter connection was one of the last to be broken when Lahontan disappeared, and it is probable that the Truckee Basin continued to overflow into the Black Rock long after the rest of the Lahontan water bodies had fully separated. The Truckee River, being headed in a region of higher rainfall in the Sierras has suffered less truncation than the other rivers of the Great Basin and has been able to keep its channel fairly clear. Several tributary valleys have lost their free outward drainage and have become somewhat saline, but they are few and insignificant. In the Lahontan period, however, Pyramid Lake received another considerable tributary which entered it from the west through a gap in the Virginia Range, bringing the drainage of the so-called Winnemucca Valley (which has no relation to Lake Winnemucca).

This drainage line has entirely decayed, and a large area once tributary to it—the Lemmon Valley, north of Reno—has been cut off by an alluvial divide and become an inclosed basin whose flat bottom carries a group of playas. This basin has an area of 90 square miles. Just north of this there is the smaller Warm Springs Basin, with an area of less than 20 square miles and separated from the Hungry Valley and the Pyramid Lake drainage by an alluvial divide over 300 feet in height. It is impossible to read clearly the history of this basin from data now at hand. It may be that the divide between it and the Truckee is quite ancient and that the Lahontan period saw it, as now, completely landlocked. However, this question is unimportant, since the basin is too small to have accumulated any considerable salt body. Including the Lemmon Valley, but not the Warm Springs Basin, the total area of the Truckee Basin is 2,975 square miles.

THE HUMBOLDT-CARSON BASIN.

The Humboldt-Carson Basin is the core of the Lahontan area. Its present bottom is a great playa covering over 500 square miles and containing in its lowest portion the Carson Sink, a shallow and variable lake of brackish water. South Carson Lake, also on the main playa, is a shallow lake produced by the meanders of the Carson River. A slough connects it with the North Carson Lake, or Carson Sink. The Humboldt River enters the playa from the north through a narrow gap near the station of Parran, on the Southern Pacific Railway. During high water of Lake Lahontan a sand bar was built across this gap, behind which Humboldt Lake has been formed. However, overflow has partially cut this bar, and at high-water stages the water of the Humboldt Lake now flows through it and into the Carson Sink.

In its upper courses the Carson River, like the Truckee, has kept some measure of its vigor and retains essentially its Lahontan drainage. Farther down, where it flows over what was once its flood plain at the margin of the retreating lake, it has left many local playas which are now without escape for their waters. All these were either covered by Lake Lahontan or were tributary to it, and have no importance in the present connection.

The history of the Humboldt River is very different. More than any other river of the Great Basin, perhaps excepting the Mojave, it has suffered by alluvial damming and by the decay of its tributaries. Its present drainage area is scarcely a half of that which it once possessed. The description of the Humboldt in detail is unnecessary. In general it may be said that it cuts across the northern extremities of the trough valleys in the eastern half of the Lahontan area, draining these valleys north as far as the limits of the Great Basin and south to the alluvial divides which separate the Lahontan drainage from that of the Colorado River and of the smaller basins to the south. Several of these trough valleys, once tributary to the Humboldt, have been cut off behind alluvial dams, creating the Buena Vista, Buffalo Springs, Crescent Valley, Gibson, and Clover Basins. Even where the valleys have not been cut off entirely, the decay of the streams has left them with innumerable local playas and alkali flats but since these are still essentially tributary to the Humboldt they do not require individual discussion.

The Humboldt and the Carson are the only important rivers tributary to the basin. A few small valleys tributary to, or filled by, the Great Lake are discussed below as the Fernley, Allen Springs, and Sand Springs Basins. The present drainage area of the Humboldt-Carson, including all local playas and other areas not cut off by actual divides, is 19,300 square miles. Its Quaternary area was 27,575 square miles.

Mention should perhaps be made of the Ragtown Soda Lakes, situated on the Carson Playa, about 6 miles northwest of Fallon. These are small depressions, probably of volcanic origin, in the bottoms of which are lakes of brine from which carbonate of soda was once made commercially. From his studies of the lakes Russell concluded that their soda content was probably derived from waters which had percolated through the saline clays of the surrounding playas and acquired salinity therefrom. They are not believed to have any important significance to the present inquiry.

The Wabuska topographic sheet of the United States Geological Survey shows another small local depression in the eastern extension of the Pine Nut Mountains about 4 miles east of Lyon Peak. Its nature is unknown to the writer, but it is too small to have any practical importance.

THE FERNLEY BASIN.

The Fernley Basin is a small depression lying between the Humboldt-Carson and the Truckee Basins, as does the Jungo Basin, between the former and the Black Rock. When Lahontan was high this basin was a strait connecting these two water bodies. On the fall of the waters the connection with the Truckee was broken first, the connection with the Humboldt-Carson, by way of Ragtown Pass, remaining much longer intact. At the present time the bottom of the Fernley Basin is about 100 feet below this pass, but it is not certain that this has always been so. Recent alluvial deposition must be taken into account and is difficult to estimate. The present bottom of the basin carries three playas, the two extreme of which drain toward the central one. All the playas are somewhat saline, but no segregated salt deposits are known. The area of the present basin is 215 square miles.

THE ALLEN SPRINGS BASIN.

South of the Carson Playa there is a deep, narrow mountain valley which was filled by the Lahontan waters and connected with them through a narrow strait at Allen Springs. The bottom of this valley is about of the same level as the Carson Playa,

but a divide over 200 feet high intervenes. This divide is probably pre-Lahontan and the Allen Springs Basin has probably always been landlocked, except when Lake Lahontan was high enough to overflow the divide. Previous connection with the larger lake is sufficient to destroy the probability of a large amount of salt having been accumulated or retained. The present area of the basin is 235 square miles and that of the playa which occupies its present depressions is 4 square miles.

THE SAND SPRINGS BASIN.

From its southeast side an arm of the Carson playa stretches into the Sand Springs Valley and is cut off from the main playa by a low and inconspicuous divide which, according to Russell, is due to a small recent fault which cuts across the mouth of the valley. East of this the surface drainage of the valley has collected in a central depression and deposited there a considerable quantity of common salt derived from the more or less saline clays which floor this part of the playa. This deposit is entirely recent and secondary, and there is no reason to suspect salt accumulations of importance to the present inquiry. In earlier times the Sand Springs Valley was filled by Lake Lahontan, and even the fault-formed divide which now exists is apparently quite recent. The drainage area cut off by this divide aggregates 200 square miles.

Just south of the Sand Springs Valley there is another arm of the main playa, also containing an alkali flat and a salt deposit, and probably possessing a similar topography and structure. These are not known in detail to the writer and the valley has been included with the Humboldt-Carson in all computations.

THE BUENA VISTA BASIN.

Turning now from those cut-off valleys previously tributary to the main Carson water body to those tributary to the Humboldt River, the first basin to engage attention is the Buena Vista. This occupies the trough extending northeastward and lying between the Humboldt and East Ranges. Toward the south the basin is barred from the Carson playa only by a low divide, and a similar low divide separates it from the Humboldt River to the north. The latter divide is apparently the lower and is alluvial, whereas King maps the southern divide as of basalt. Both divides were overtopped by the waters of Lahontan, but the southern was probably the earlier exposed and in the latest Lahontan stages the Buena Vista Valley was probably a tributary of the Humboldt River. The present bottom of the valley is occupied by a playa of the usual character and with an area of about 50 square miles. The total area of the present basin is about 4,000 square miles, but this area is somewhat uncertain, because the position of the alluvial divide at the northern end is not exactly known.

THE BUFFALO SPRINGS BASIN.

The Buffalo Springs Basin is a small valley lying north of the Battle Mountain range and separated from the Reese River only by a low divide composed partly of alluvium and partly of blown sand. This divide appears to be very recent and there can be little question that the time is short since the drainage of the basin found free egress to the Reese River and thence to the Humboldt. The area of the basin is about 500 square miles, there being again some uncertainty as to the exact position of the recent divide. It contains a playa approximately 25 square miles in area.

THE CRESCENT VALLEY REGION.

East of the north-south trough occupied and drained by the Reese River and extending eastward as far as the Sulphur Springs Range is an area of rather complicated topography in which the north-south trend of valleys and ranges, while still traceable, becomes less obvious. This area has been very inadequately mapped, and the infor-

mation at hand is not sufficient to permit a detailed statement of its past and present drainage conditions. However, a brief personal visit indicates that it is divided by the east-west uplift of the Simpson Park and Roberts Mountains into two divisions of different affiliations. South of this uplift lie the Monitor, Kobeh, and Dry Valleys, which drain or drained to the Diamond Valley. North of the divide the country was once tributary to the Humboldt River and comprised two northward-flowing stream systems—that of Horse and Pine Creeks to the east and that of the Grass and Crescent Valleys to the west, the two being separated by the Cortez Mountains. Both of these drainage lines have suffered severely by stream decay and have been broken into numerous shallow basins and local playas, the exact limits of which can not be determined from existing information. So far as known there are no areas of considerable or long-continued drainage concentration, and all playas and marshes are believed to be not only local but very recent.

The total area of the region believed to have been tributary to the Humboldt is 2,430 square miles.

THE GIBSON BASIN.

East of the Sulphur Spring Range, which forms the eastern border of the Crescent area, the parallel troughs and ranges again become the distinctive features of the topography. The first of the troughs is mainly occupied by Diamond Valley, which has probably always been landlocked, and will be discussed among the trough valleys of Nevada. East of this, between the Diamond and Ruby Ranges, lies the great trough of the Huntington and Gibson Valleys, which, bending a little to the west, extends southward through the Little Smoky, Hot Creek, and Reveille Valleys, well below the thirty-eighth parallel. The northern part of this trough, containing the Huntington and South Fork Valleys, now drains to the Humboldt. Just south of this is the Gibson Valley, the northward drainage of which is cut off by a low and poorly defined divide southwest of Hastings Pass. This divide is probably largely alluvial, but may be due in part to minor and local cross-uplift. At any rate, it is believed to be recent, and the Gibson Valley is believed to belong to the former drainage of the Humboldt. Another alluvial divide cuts the Little Smoky Valley just north of the thirty-ninth parallel into two divisions, one of which drains northward into the Gibson, the other southward into Hot Creek and Railroad Valley. This divide marks the southern limit of the Lahontan Basin in this trough. The area of the Gibson Basin, including the tributary part of the Little Smoky Valley, is 1,150 square miles. It contains a long, narrow playa (Newark Lake) having an area of over 30 square miles. This playa is somewhat saline, but the salinity is believed to be recently acquired and the conclusion of recent outward drainage removes any expectation of extensive salt deposits.

THE CLOVER GROUP OF BASINS.

The north-south mountain line represented by the Ruby Range is almost everywhere the line of the Bonneville-Lahontan divide, but beyond the northeast corner of this range and perched on the very crest of the divide lies the Clover group of three closely connected basins which are believed to have belonged to the Lahontan division. This group consists of two parallel north-south valleys, the Clover to the west and the Independence to the east, separated in their northern parts by the Independence Mountains. To the south these mountains vanish and the valleys merge. Independence Valley contains two local depressions due to recent alluviation and containing playas of the usual type. Clover Valley has a single depression, which is the deepest in the group and contains the shallow water body of Clover or Snow Water Lake. Independence Valley is completely landlocked except for its connection with Clover Valley. The latter has two low passes, one north into the Humboldt River, about 200 feet above the valley bottom and the other south into the Ruby Basin and a little

higher. The former is alluvial and is believed to be recent. The latter is mapped by King as basalt. It is very probable that the early drainage of this group was northward into the Humboldt, and their interest to the present inquiry, accordingly, disappears. The total area of the group is 1,075 square miles.

THE WALKER BASIN.

There remains for discussion only this one division of the great Lahontan water body. It lies south of the Lahontan body proper, and consists essentially of two north and south troughs lying on either side of the Walker Range. Rising in the Sierras, the Walker River flows northward through the western trough, around the north end of the Walker Range, and into the deeper eastern trough, the deepest depressions of which contain the present Walker Lake. Structurally, the affiliations of the Walker trough are much more with the isolated trough valleys to the east and south than with the valleys of the main Lahontan area. Only the accident of a low pass to the north enabled the early Walker Lake to overflow and establish a connection with Lake Lahontan. This connection was never a deep one, and the Walker body was the first of the main Lahontan water bodies to become separated when the lake began to fall. It is probable that it continued for a time to overflow into Lahontan, but advancing desiccation must have put an early end to this, and the independent history of the Walker Basin is probably a fairly long one.

Like the Truckee and the Carson, the Walker River has been able to keep its stream fairly vigorous and its main channel fairly clear, but numerous local playas and 'alkali' flats have been formed in the tributary valleys. Most of these are too local and recent to deserve especial notice. The most important is the chain of two basins north of the Gillis Range and now separated from the Walker Valley and from each other by low alluvial divides. Several similar basins border the Walker River in its northward course through the western trough.

Along the west Walker River (a branch of the main river) are several basins which are interesting because of their less usual origin, though no more important to the present inquiry. It seems that the upper course of this river was once a series of lake basins apparently of structural origin. In the course of time the river cut narrow canyons through the walls of these basins and drained the lakes. But, this done, the river has sometimes deserted the axis of the basins for a channel along a traversing delta of its own building, leaving to one side or the other depressions still below the river or its outlet. With complete desiccation these depressions have become undrained basins with central playas of usual type. This appears to be the history of the playa in the north end of Smith Valley. The playas and alkali lakes of the Antelope Valley probably owe their origin in part to similar processes, though these processes have been much complicated by fan-building and alluvial deposition.

The area of the Walker Basin at the present time is approximately 3,200 square miles. Including all the areas once tributary to it but now cut off by damming or stream decay, it covers 3,850 square miles. Walker Lake has a present area of 104 square miles, but this has varied greatly in the recent past, as is attested by the extensive and complete system of old-shore lines which surrounds it.

THE BONNEVILLE BASIN AND ITS TRIBUTARIES.

Though somewhat larger than the Lahontan Basin, the Bonneville Basin is much more nearly a unit. In Lahontan time it received the drainage of all the inclosed region east of the Bonneville-Lahontan divide, its deepest portion being occupied by the Great Lake Bonneville, with an area at its highest stage of nearly 20,000 square miles.

This early lake and its history have been fully studied by Gilbert,¹ and the reader is referred to his report for all details. From the present viewpoint the most important feature of Gilbert's work is the conclusion that the lake acquired and long retained an outlet into Snake River and thence to the sea. During the greater part of the existence and fluctuations of Lake Lahontan, Lake Bonneville was an overflowing lake of normal character and was undoubtedly fresh. This fact alone is sufficient to remove most of the importance of the basin to the present inquiry. The salt contained in the Great Salt Lake, which is the present remnant of Lake Bonneville, is simply that present in the waters of the early lake at the time when overflow finally ceased plus that added in the drainage since that time. However large, it is probably not comparable with that which accumulated in Lake Lahontan.

The present Bonneville Basin is divided by a low and recent parting into the basin of the Great Salt Lake to the north and the Sevier Basin to the south. Local divides, for the most part recent as well, have cut off a few small basins from the two main divisions. The total drainage area of the Bonneville Basin during the Lahontan period was 57,960 square miles.

THE GREAT SALT LAKE BASIN.

This basin is the central remnant of the original Bonneville Basin and includes the valley of the Great Salt Lake and all valleys now tributary thereto. The north-south trend of ranges and valleys, though here less marked than in the Lahontan Basin, is still quite distinct and the long parallel ranges form islands in the present lake or divide the trough valleys which drain into it. As in the Lahontan region, desiccation and stream decay have reduced the vigor of the rivers which once occupied these valleys and many local playas and marshes have been produced. The chief present tributaries of the Great Salt Lake are the Bear River from the north, the Weber River from the east, and the Jordan River and Utah Lake drainage from the south. Having their sources in well-watered highlands, these streams have retained a considerable measure of their former vigor and are, indeed, largely responsible for the persistence of the Great Salt Lake itself. There was once another considerable tributary entering the lake from the southwest through the Snake Valley. This has entirely decayed and the Snake Valley and some of its tributaries have acquired small local playas and brackish marshes of very recent origin. The obstructions to drainage out of the valleys are not considerable even now, and would be overcome and removed by a very moderate increase in average rainfall.

The Great Salt Lake has a present area of about 2,200 square miles and a maximum depth of approximately 50 feet, being somewhat variable in both dimensions. It is extremely saline. West and southwest of the present lake is the Great Salt Lake Desert, a broad playa-like flood plain but recently abandoned by the lake and covering an area of over 3,000 square miles. Innumerable local depressions in this plain have become small and shallow areas of inclosed drainage and salt concentration and have come to contain greater or lesser deposits of common salt formed essentially like the Sand Springs salt deposit described on page 16. The divides between these

¹ U. S. Geol. Sur., Monog. I (1891).

little basins are indistinguishable and never more than a few feet in height. A very slight increase in rainfall would be sufficient to flood and drain them and wash their salt back into the Great Salt Lake.

The present area of the Great Salt Lake Basin is perhaps 25,000 square miles. Including the Great Salt Lake Desert and the other similar areas of local playas and marshes, but excluding the basins cut off by real though recent divides, the area is 33,760 square miles. Including former tributaries, now the Steptoe and Ruby groups, and the White Valley, Rush, and Cedar Basins, the area is 42,300 square miles.

THE STEPTOE BASIN.

During the Lahontan period one of the main tributaries of Lake Bonneville headed between the Egan and Schell Creek Ranges, well south of the thirty-ninth parallel, flowed northward through the great trough of the Steptoe and Goshute Valleys, crossed the Toano Range and entered Lake Bonneville east of the present railroad station of Cobre. Since that time alluvial deposition, probably assisted by local uplift, has barred the pass in the Toano Range and cut off the Goshute Valley from discharge. At the same time alluvial damming and stream decay have broken the former through-flowing stream into a score of separate basins, each with its local playa and each separated from the other by low and indistinguishable divides. The whole valley has become an area of practically no drainage and no point or points of considerable concentration can be distinguished. This early drainage line still receives the insignificant discharge of what was once a considerable stream from the Antelope Valley, and it once received also the drainage of the Ruby group about to be described. The area of the Steptoe, Goshute, and Antelope Valleys with their tributaries is 3,930 square miles. Adding the Ruby group, the total becomes 6,590 square miles.

THE RUBY GROUP OF BASINS.

The Ruby group lies on the crest of the Bonneville-Lahontan divide, south of the Clover group already discussed and between the Ruby and Egan Ranges. It consists of the Ruby Valley to the north, with two parallel north-south valleys, the Butte and the Murray¹ lying south from it and formerly tributary to it. The deepest depression of the Ruby Valley proper lies at its western edge under the steep slope of the Ruby Range and contains Ruby and Franklin Lakes. Eastward from this depression the valley rises very gradually toward the low gap of the Goshute Pass between the Egan and Pequop Mountains. It is reasonably certain that the Ruby Valley previously discharged through this gap into the Goshute Valley and thence to Bonneville. The topography of the pass is complicated by alluvial deposition and apparently by recent and local movement, and it is not possible to determine with assurance whether the Ruby Valley of the Lahontan period had an unresisted drainage into the Goshute Valley or contained a lake which overflowed thereto over a permanent dam. The writer has not found conclusive signs of lake occupation in the Ruby Valley and hence inclines to the former opinion. In either case the valley lacks interest from the present viewpoint.

Of the southern tributaries of the Ruby Valley, the Butte Valley is confined only by a low and inconspicuous divide across its northern end. This divide is alluvial and probably very recent, and there can be little question of the previous free drainage of the valley toward the north. It contains a rather poorly developed playa with an area of approximately 12 square miles. The Murray Valley is separated from the Ruby Valley by divides of similar character, but higher and better defined. They too are believed to be post-Lahontan, and the earlier outward drainage is be-

¹ This valley is known locally as Long Valley, but there being numerous other Long Valleys in the Great Basin, and this name being in general use for another basin (see p. 29), it is impossible to retain it here.

lieved to have been unrestricted. The valley now contains a number of local playas, but no area of considerable drainage concentration is known.

The Ruby Valley proper has a present drainage area of 1,200 square miles, Butte Valley has 740 square miles, and Murray Valley 720 square miles, making a total area of 2,660 square miles for the group.

THE WHITE VALLEY BASIN.

The White Valley Basin is a north-south trough lying between the Confusion and the House (or Antelope) Ranges and directly south of the Great Salt Lake Desert. It is essentially structural in origin and is entirely surrounded by mountains or hills. However, the lower hills to the north were overtopped by the waters of Lake Bonneville, and even on the recession of these waters it is probable that the White Valley maintained for a time an outflow to the Great Salt Lake Basin, either through the low hills west of the Fish Spring Range or through Sand Pass Canyon between this range and the House Range and leading into the Fish Spring Valley. Both of these passes are now over 300 feet above the floor of the valley, but may have been raised by recent alluvial deposition. In any event, the separate existence of the White Valley Basin can not antedate the final recession of the waters of Bonneville. The area of the present basin is 920 square miles, and it contains two playas separated by a low alluvial divide crossing the valley from east to west somewhat south of its middle. The northern playa is the larger and probably slightly the lower.

THE RUSH VALLEY BASIN.

The Rush Valley is essentially similar to that last discussed, but lies north and east from it between the Onaqui and Stansbury Mountains on the west and the Oquirrh Range to the east. The surrounding divides are entirely structural, but the valley originally drained into that of the Great Salt Lake through a gap in the northern divide just north of the present town of Stockton. This gap was below the waters of Bonneville and the waves of that lake built a sand bar across it. When the waters receded this bar became a dam essentially similar to the one formed by Lahontan, at the southern end of Humboldt Lake, as described on page 14. In this case, however, the dam has never been breached and the drainage of the valley is still retained behind it, forming a small brackish lake in a portion of the pre-Lahontan river channel. The area now tributary to this lake is 700 square miles.

THE CEDAR VALLEY BASIN.

This is a third basin essentially like those of the White and Rush Valleys. It lies just east of the latter and between the Oquirrh and Lake Ranges. The latter range is low and poorly defined and the waters of Lake Bonneville transgressed it in several places, forming of the Cedar Valley a partially inclosed sound separated from the water body of Utah Lake Valley on the east by a chain of islands. There is also a fairly low pass leading westward from the Cedar Valley into the Rush Valley described above, and it is possible that this also was below the highest stage of Lake Bonneville. To the east the connection with the Utah Lake Valley was probably retained until quite late in the recession of the great lake and the inclosed character of the Cedar Valley appears therefore to be quite recent. Its present area is 300 square miles. It contains two playas of usual character.

THE SEVIER BASIN.

Structurally the present Sevier Basin consists of three parallel troughs trending approximately north and south. The middle of these, though the largest and probably the deepest, is less well defined than the others. In its northern portion it expands to form the great filled valley of the Sevier Desert. In its middle portion it is com-

paratively narrow and is further narrowed by the north-south range of the Mineral Mountains, almost equidistant between its sides. Farther to the south it bends westward and again expands into another filled valley, the Escalante Desert.

The easternmost of these three troughs is much more regular and stretches almost unbroken from the fortieth parallel to the Arizona line, being bordered on the west by the continuous uplift of the Parowan, Tushar, Pavant, and Canyon Ranges and on the east by the western scarp of the high plateau country. Essentially this valley is but a southward extension of the Jordan and Utah Lake Valleys, the depression which lies just beneath the great west scarp of the Wasatch Range. But only the southern part of this trough belongs to the Sevier drainage, the parting being the local uplift of the Tintic Mountains, and a low divide, probably alluvial, in the Juab Valley at the same latitude. This southern half of the trough is occupied by the northward-flowing Sevier River, which, paralleling the behavior of the Humboldt, turns westward across the north end of the Canyon Mountains through the deep Sevier Canyon and enters the middle or main trough of the basin.

The westernmost trough is well defined but less than half the length of the others. It consists of the Sevier Lake and Preuss Valleys and merges to the north into the Sevier Desert. It is interesting mainly because it contains the present deepest depression in the basin, the sink of Sevier Lake.

At the higher stages of Bonneville the middle and western troughs were largely filled with the waters of the lake. The easternmost trough is higher and was not filled, except for a small embayment at the northern end. It contained a northward-flowing river, the predecessor of the present Sevier, which emptied into this embayment. When the waters of Bonneville fell low enough to expose the comparatively low divide separating the Sevier Basin from that of the Great Salt Lake, the former continued for a time to overflow into the latter through a well-marked channel which may still be seen east of McDowell Mountain and which has been described by Gilbert.¹ With increasing desiccation the outflow of the Sevier Valley ceased and its basin attained the inclosed character which it now exhibits.

At the present time the central and western troughs have become areas of practically no drainage. The northern end of the former—the Preuss Valley—has been cut off from Sevier Lake by a low alluvial divide, while the Escalante Desert has been similarly separated from the central trough. The eastern trough has more nearly retained its original character. The Sevier River is still a fairly vigorous stream until it begins to cross the Sevier Desert. Here it loses itself in a succession of meanders and local marshes, reaching the lake only in time of flood. It is probable, however, that this failure to reach the lake continuously is very recent and due to the large use of the waters for irrigation. The Sevier Desert itself is a succession of local playas much like the Great Salt Lake Desert, but less saline and more often having free but unused drainage channels to the sink. Rush Lake and Parowan Valleys east of the Escalante Desert were once freely drained to the main lake body, but have been cut off by stream decay and now contain small saline lakes. Round Valley, east of the town of Manti, is a small structural basin of the type of the White Rush and Cedar Valleys above described. How long it has been a separate drainage unit is not fully certain—probably not very long and in any case its area of 170 square miles is too little to give it any importance to this inquiry. At the present time the area from which Sevier Lake receives even occasional drainage is probably not over 10,000 square miles. During Lahontan time the Sevier Basin, including Parowan, Rush Lake, Round, and Preuss Valleys, the Escalante Desert, etc., had a total area of 16,375 square miles.

¹ U. S. Geol. Sur., Monog. I, p. 181 (1890).

THE BASINS OF THE LAVA PLATEAU.

The eastern two-thirds of Oregon and the southeastern quarter of Idaho, with contiguous portions of Nevada and California, are covered by great sheets of Tertiary lavas. In its northerly portions the plateau thus formed, though considerably dissected, is substantially level, but its southern portion has been invaded by the area of uplift and faulting which created the valleys of the Great Basin, and has been split into a number of valleys and ranges of purely structural origin. In the main there has been little flexure and the faulting is usually of a simple monoclinical type. As before, the main lines of displacement run north and south, but there has been a significant degree of irregular movement along lines otherwise directed, and the valleys of the region possess only in lesser degree the simplicity and regularity of structure characteristic of the trough valleys of central Nevada. The topography being dependent on the monoclinical structure, is everywhere much the same. The valleys are long and relatively narrow, with a gentle, somewhat dissected slope on one side and a steep fault scarp on the other.

Many of the valleys of this region possessed from the beginning an open drainage to the sea or soon attained it through the breaching of the surrounding divides. (Pl. II, fig. 1.) Many of these still retain this open drainage or have lost it only recently. However, the portion of the area contiguous to the Great Basin proper has been, like it, a region of low and topographically insufficient rainfall and many of its valleys have never had a seaward drainage. All of the valleys which are now areas of inclosed or restricted drainage are briefly described below. The Honey Lake Basin, described among the Lahontan group, is not essentially dissimilar to the basins of the lava plateau, and owes its connection with the larger group to the chance occurrence of a low pass leading thereto.

THE CHRISTMAS LAKE VALLEY.

The Christmas Lake Valley is the extreme northwest basin of the group and is perhaps the least typical of all. It lies about at the extremity of the region of profound monoclinical faulting and is characterized more by gentle folding and by minor and irregular displacement than by the well-defined fault lines so prominent to the south. The basin is bordered on all sides by rolling plateaus formed by gentle folding of the lava and modified by a comparatively slight subsequent erosion. Undoubtedly these rolling plateaus once possessed more or less well-defined drainage systems, but increased desiccation has entirely destroyed them or reduced them to mere vestiges. The whole region is now one of no determined drainage. This makes it nearly impossible to fix accurately the boundaries of the basin. On all sides the plateau is dotted with innumerable small pans or playas each of which receives and retains the drainage of a greater or lesser surrounding area. (Pl. II, fig. 2.) Most of these small basins represent irregularities in the folding of the plateau and are therefore structural and original, but there can be little doubt that nearly if not quite all of them once overflowed either inward toward the Christmas Lake Valley or outward into the surround-

ing basins or into the Columbia River. In many cases it is now impossible to determine the original direction of drainage of these pans and both for this reason and because of the inadequacy of the available maps, the divides have been only very roughly determinable and the calculated area is very approximate indeed. This applies particularly to the Great Sandy Desert, across which passes the northern boundary of the Christmas Lake Basin. This is a region of very low relief. The slopes are usually not determinable except by precise leveling and most of the drainage channels which once existed have been wholly or partly obscured by dune sand and alluvium.

The present floor of the Christmas Lake Valley is a broad plain, apparently flat and diversified by several dune areas, especially in its eastern part. It rises more or less gently to the surrounding rolling plateau and shows none of the usual features of lake or playa topography. It is quite possible that it had once an outlet reaching from its northwest corner through the Fort Rock Valley and the Deschutes River to the Columbia. This region has never been mapped and was not carefully examined by the writer. The question must be left open, though the assumption of recent and reasonably free outlet would explain the absence of playa or lake traces and the general topographic resemblance to a tributary rather than a receiving valley, matters which are difficult to understand on the assumption of continuously inclosed conditions.

Christmas and Fossil Lakes, with several other small playas or marshes now present on the valley floor, are mere local depressions formed by wind erosion or dune movement, or both, and fed by springs or local drainage. Christmas and Fossil Lakes owe their comparative permanence to supply from springs. Neither has any relation to the earlier topography of the valley. Thorne Lake, in the southwestern corner, is a small enlargement and local depression in the channel through which the overflow of Silver Lake once passed into the Christmas Lake Valley.

At the present time there is no area of considerable drainage concentration in the valley. Peter Creek, rising in the southern slopes of the Pauline Mountains, maintains a well-defined channel for some distance southward, but finally loses its water to the underflow without forming a lake or playa. Christmas and Fossil Lakes receive the drainage of their immediate surroundings only. During the Lahontan period the drainage area was about 2,000 square miles, exclusive of the Silver Lake Basin, next described. Including this, the area was about 2,750 square miles. Because of the difficulty of determining the actual position of the limiting divide, the figure for the Christmas Lake Valley proper is scarcely more than a rough approximation.

THE SILVER LAKE BASIN.

Silver Lake lies southeast of the Christmas Lake Valley, in a basin of structural origin and bounded by lava scarps and slopes in the manner typical of the region. To the west and southwest its drainage reaches to the crest of the lava plateau and a somewhat indefinite parting from the headwaters of the Klamath River drainage. Between it and the Christmas Lake Valley is the small but steep local uplift of the Conley Hills and Table Rock. There are several low gaps in this uplift, and one of them, south of Table Rock, is only a few feet above the present Silver Lake and contains a dry channel through which Silver Lake discharged into the Christmas Lake Valley very recently indeed. The present Silver Lake occupies the southern portion of its valley, the northern portion being occupied by the Pauline Marsh, which empties southward through the Pauline Slough. The lake is very shallow but practically fresh, a fact which is accounted for by the recency of overflow. The lake is somewhat variable in size and is reported to have entirely evaporated in 1886-87. The present drainage area is essentially the same as that of the Lahontan period, and is about 750 square miles. There is some uncertainty in the position of the divides in this area, but the uncertainty is far less than in the case of Christmas Lake Valley.



FIG. 1.—KAMAS PRAIRIE, NEAR LAKEVIEW, OREG.

[A typical filled lake. The outlet is through the gap visible in the opposite rim.]



FIG. 2.—SMALL INCLOSED PAN ON THE LAVA PLATEAU NORTH OF THE CHRISTMAS LAKE VALLEY, OREG.



FIG. 1.—SOUTHEAST CORNER OF ABERT LAKE, OREG.

[The high-water line of the ancient lake is visible about one-fourth way up the mountain slope on the right.]



FIG. 2.—PLAYA OF ALKALI LAKE, OREG.

[Showing the Lahontan period lake terraces at the foot of the mountains in the distance.]

THE CHEWAUCAN BASIN AND ABERT LAKE.

The Chewaucan Basin lies between the north-south fault scarps of two outward dipping monoclines. On the west is the Winter Ridge, bounded by the 2,500-foot scarp west of Summer Lake and dipping westward to the valleys of the Klamath and the Deschutes. On the east is the similar scarp east of Abert Lake, and beyond that the gentle eastward slope of the monocline down to the Warner Valley. The two fault lines which determine these scarps come together south of Abert Lake and are lost in a region of general uplift which forms the divide between the Chewaucan Basin and the Goose Lake Basin to the south. Toward the north the fault lines diverge, and the basin is bordered by the rolling lava plateau already described in connection with the Christmas Lake Valley. The drainage of this is scarcely at all determinate and the divides between the Chewaucan and the Alkali and Christmas Lake basins are correspondingly uncertain.

The deepest depressions of the basin lie just beneath the greatest heights of the scarps and are occupied respectively by Summer Lake on the west and Abert Lake on the east. Both of these lakes are very shallow. Summer Lake is bordered by a playa area on the north and east and Abert Lake on the north only. Summer Lake is about 200 feet higher than Abert and was once connected with it through the Chewaucan Marsh. This connection is now broken just south of Summer Lake by a low alluvial dam probably due in part to delta and fan formation by the Chewaucan River, which enters the valley just at this point. The divides surrounding the basin as a whole are high and structural and there is no indication of any previous overflow. Abert Lake is surrounded by terraces indicating that the water body has been much larger and deeper than now. (Pl. III, fig. 1.) The heights of these terraces have not been measured accurately, but hand-level and aneroid measurements place the highest of them at about 200 feet above the lake. The terraces can be traced about the Chewaucan Marsh, but not into Summer Lake, the present elevation of this lake being very nearly that of the highest terrace. It is probable that the present Summer Lake was once a shallow bay or filled estuary of the early water body, and that it was then cut off from the main body by wave accumulation and delta building, the details of which have been obscured by subsequent rainwash. It is impossible to determine the date of this separation or whether or not Summer Lake continued for a while to overflow into the Abert body. The present inclosed character of the lake may have originated during the maximum of the lake expansion or it may have been initiated only very much later. The writer inclines to the latter opinion, but, in any case, Summer Lake was once a tributary to Abert, and any extensive salt accumulations should be looked for in or under the latter rather than in the former.

The drainage of both Summer and Abert Lakes is now slightly less than formerly, because of the decay of the drainage from the pans of the plateau region to the north, as already described in connection with the Christmas Lake Valley. The Antelope Valley south of Abert Lake was apparently once a small mountain lake which has been drained by the cutting of the gorge of Crooked Creek and at the same time filled by alluvium. At present it has unrestricted though meager drainage to Abert Lake. Except as water is used for irrigation, the Chewaucan River and Marsh drain freely into Abert. The area now tributary to Abert, including everything except Summer Lake, is about 930 square miles. The Summer Lake drainage totals about 560 square miles, making nearly 1,500 square miles for the two. These figures are open to slight uncertainty because of the indefinite character of the northern divide. The present area of Summer Lake is 75 square miles and that of Abert Lake 60 square miles.

THE ALKALI LAKE BASIN.

The Alkali Lake Basin is essentially a northward extension of the Abert Lake trough and is separated therefrom by the region of local cross uplift in the vicinity of Euchre Butte. On the east the basin is bordered, like Abert, by the scarp of an eastward dipping monocline which merges toward the north into the less simple uplifts of Little Juniper and Wagontire Mountains. To the west the basin is separated from the Christmas Lake and Summer Lake Valleys by the usual inconspicuous divide across the lava plateau. It appears that the lake once received from this direction a main tributary which drained the pans and valleys of the lava plateau north of Sheep Rock. This drainage line has now been cut off almost entirely, and the lava plateau has been divided into numerous local basins.

The deepest depression of the valley is Alkali Lake, a playa lake of very variable size. In the dry season it is usually reduced to three or four saline ponds occupying wind-eroded depressions in the playa. (Pl. III, fig. 2.) The northern extension of the Alkali Lake Valley, called "North Alkali," is now cut off from the main valley by a dam of wave and dune sand and has become somewhat saline. However, this separation is quite recent and does not affect the unity of the valley. A series of terraces about both North and South Alkali Valleys indicates previous occupation by a considerable lake, and, as all divides are far above these terraces, the lake must always have been inclosed. The drainage area of the lake was about 400 square miles, which has been reduced to perhaps a third of this value by the cutting off of North Alkali and of the pans of the plateau.

THE WARNER BASIN.

Mention has already been made of the eastward-dipping monocline the limiting scarp of which forms the eastern boundary of the Abert Lake Basin. This monocline is limited on the east by the scarp of a second monocline of precisely similar nature, and between the two scarps lies the Warner Valley. As usual, the deepest depression lies immediately under the scarp, being accentuated in this case by a minor parallel faulting to the west of the axis of the depression. The depression is a long narrow valley between a high steep scarp to the east, and to the west a much lower scarp from the crest of which rises the gentle monoclinical slope before mentioned. To the north and northwest the valley rises into a rolling plateau like those already described, and across which passes the inconspicuous divide between it and the Harney Basin. At the south the basin is limited by a zone of cross uplift and irregular faulting, beyond which lies the Surprise Valley.

The Warner Valley is entirely surrounded by high divides and seems to have been always so inclosed. The surrounding mountains are furrowed by a series of lake terraces of usual character, the highest of which is (by aneroid) a little over 200 feet above the present lake. Several streams descend the gentle slope of the westward monocline and reach the valley proper through narrow canyons cut in the basalt of the low western scarp. During the lake period nearly all of these streams built typical deltas, the remnants of which may still be seen. (Pl. IV, fig. 1.)

The present floor of the valley is a flat clay plain, probably once a playa, but now diversified by considerable vegetation and by occasional dune areas or wind-scoured hollows. Shallow depressions hold two main lakes and several smaller ones, the whole being known as the Warner Lakes. All of the lakes are either fresh or merely brackish, but at the southeast corner of the northern or Upper Lake is a small pond containing a nearly saturated solution of sodium chloride. Its salt is believed to be derived from seepage. The separation of the Warner Lakes is very recent. They are still variable in size and are reported to have been considerably larger about forty years ago.

The only part of the basin which has suffered severely by stream decay is the long western slope. Here many once vigorous streams have dwindled to little or nothing and have ceased to overflow a few local depressions. In nearly every case, however, a very slight increase of rainfall would be sufficient to clear and restore the drainage, and it can not be believed that the present cut-off condition is of any considerable antiquity. This can not be so surely said of Juniper Lake, east of Adel. The basin of this lake, though small, is relatively deep, and Waring¹ reports two old strands on its walls. It may have been inclosed for a considerable time, but the small size of the basin destroys any present interest which it might have.

At present the area tributary to the Warner Lakes as a whole is perhaps not over 1,500 square miles but during the Lahontan period the drainage area was probably slightly over 2,000 square miles, there being some uncertainty as to the exact position of the northern boundary.

THE HARNEY BASIN.

East of the Christmas Lake Basin is another of very similar character—the Harney Basin. As before, the divides are inconspicuous and run over plains and rolling plateaus of little relief. In the case of the Harney, however, there is no question of the recency of overflow. Russell² explored and described the channel through which the basin discharged into the Malheur River, and which is now stopped by a dam of recent lava. Behind this dam the valley is broad and flat and the impounded waters, instead of overflowing the dam, have spread out to form Malheur and Harney Lakes.

THE CATLOW VALLEY AND GUANO LAKE.

It will be recalled that the eastern side of the Warner Valley was mentioned as bordered by the west scarp of an eastward-dipping monocline, the crest of which forms the Warner Mountains. Still farther east the Steens Mountains form a similar range, but higher and of opposite inclination. In this case the scarp faces eastward, while the gentle slope is toward the west. Essentially the area between these mountains is a gentle syncline with its trough running approximately north and south and its flanks cut off by the Warner and Steens Mountain scarps. In detail this simple structure is far from apparent. The region is one of gently rolling lava plains, much like those already described and with its topography modified by local and irregular folding and faulting and possibly by erosion. It is little known and very inadequately mapped, and desiccation has destroyed or obscured most of its drainage lines. Its division into specific “basins” is therefore nearly impossible and is not attempted. It is possible to point out only that there are at least two areas of considerable concentration of drainage, the northern in Catlow Valley and the southern in Guano Lake. The Catlow Valley is of the usual flat-floor type with a shallow intermittent lake. It receives the drainage of Rock Creek from the west and of a part of the Steens Mountains slope from the east. Concerning Guano Lake, scarcely anything is known beyond the fact that it receives the flow of Warner Creek coming from the crest of the Warner Mountains to the west.

At its northeast corner a narrow pass opens from the Catlow Valley into the valley of the Donner and Blitzen River, one of the tributaries of Malheur Lake. The present divide in this pass is less than 300 feet above the level of the Catlow Valley, and it is natural to assume that this pass was previously a discharge channel, the present divide having been created or raised by subsequent alluvial deposition. However, Waring³ reports that the Catlow Valley is surrounded by old strand lines and that these are below the divide. It may be, however, that the strands belong to a recent

¹ U. S. Geol. Sur., Water Supply Paper 231, 29 (1909).

² U. S. Geol. Sur., Bul. 217, 22 (1903).

³ U. S. Geol. Sur., Water Supply Paper 231, 65 (1909).

and transient lake and that the basin was freely drained during the main Lahontan period. This could be determined only by extensive detailed study. Nothing at all is known concerning the Quaternary history of Guano Lake. The writer inclines to the opinion that it previously drained into the Catlow Valley, but the evidence favoring such a conclusion is too insignificant to warrant its acceptance.

The present drainage of the Catlow Valley aggregates perhaps 1,000 square miles. During the Lahontan period about as much again is believed to have been tributary to it, making a total of about 2,000 square miles. The remainder of the syncline, including the Guano Lake Basin, has an area of approximately 1,000 square miles, which may or may not have been tributary to the latter.

THE SURPRISE BASIN.

The Surprise Valley is a north-and-south trough lying immediately south of the Warner trough and appearing at first sight to be a continuation of it. Closer examination, however, casts considerable doubt upon this conclusion. The structure of the Surprise trough is much more complex and has never been studied in detail. The deepest depression and highest range are here on the western side of the valley, and if the structure is monoclinical the inclination is reversed from that exhibited in the Warner. From a cursory examination of the valley and the range which borders it on the west, the writer is inclined to the opinion that folding has had almost as much to do with the structure as has faulting and that the appearance of analogy to the Warner Valley is appearance only. To the north the valley rises rather suddenly to the highlands running east from Mount Bidwell and which separate it from the Warner Valley. The structure of these highlands is also unknown. Southward and eastward the valley rises more gradually to a relatively undisturbed lava plateau, the features of which are due to folding and erosion much more than to faulting. The low and featureless range which separates the Surprise Valley from Long Valley on the east suggests a gentle anticline of north-south axis, but this is by no means certain.

The present floor of the valley is very similar to that of the Warner Valley, being essentially a great playa, in shallow depressions of which stand the Upper, Middle, and Lower Surprise Lakes. This plain is somewhat less diversified than that of the Warner and its playa character is more apparent. The lakes are very variable and it is reported that the northern or Upper Lake sometimes evaporates entirely to dryness. The Lower or southernmost lake is connected with the Middle Lake by a narrow slough, the latter being separated from the Upper Lake by a low alluvial divide. A series of old strands of usual character surround the whole valley and indicate previous occupation by a single great lake which stood about 350 feet above the present floor and was permanently without outlet. This lake has left wave bars, terraces, etc., which rival in completeness those of Lahontan and Bonneville. Lake Annie, north of Fort Bidwell, lies behind a wave bar of this kind built across the mouth of a narrow canyon which was an estuary of the ancient lake.

On the crest of the northern divide, east of Mount Bidwell, lies the small basin of Cowhead Lake, once a tributary of the Surprise, but now cut off by desiccation. New Year Lake, near the crest of the eastern divide, is of similar character. South of the valley the large basin of Duck Flat, also at one time a tributary and later filled by an arm of the ancient lake, has been cut off by a low and recent alluvial divide to form an inclosed basin.

The present tributaries of the valley include only a number of short mountain streams, mostly intermittent in character. The area now tributary to the valley is about 900 square miles. With Duck Flat and the basin of Cowhead and New Year Lakes the area is 1,580 square miles. It is possible that Long Valley, to the east, was also once tributary to the Surprise. If the area of this be included the total becomes 2,350 square miles.

THE LONG VALLEY BASIN.

Long Valley lies just east of the Surprise Valley, beyond the crest of the gentle anticline (?) already mentioned. It is a poorly defined valley the detailed structure of which is very complex. On all sides it merges with the folded and dissected lava plateau already mentioned. Its floor is an irregularly shaped playa dotted with shallow and variable lakes, between which are very low and inconspicuous divides. Several low passes lead out of the valley at about the same elevation, one to the Coleman Valley (a tributary of the Warner Basin) and the others either to Duck Flat or directly to the Surprise Valley. Without detailed examination it is not possible to determine which of these, if any, was a channel of ancient discharge. The writer inclines to the opinion that during the Lahontan period there was free or overflow discharge into Duck Flat and thence to the Surprise Valley, but this conclusion can not be considered certain. The present lakes are fresh or brackish only. It is not possible to determine the present drainage of each. The area of the whole valley is about 775 square miles.

THE ALVORD VALLEY.

It will be recalled that the shallow syncline of the Catlow and Guano Valleys was bordered on the east by the uplift of the Steens Mountains. The eastern face of this range is a high fault scarp, directly below which lies the Alvord Valley. Like the Warner and Abert Valleys it is essentially monoclinal in structure, though an anticlinal structure previous and parallel to the faulting has been detected by both Russell and Waring. In the Steens Mountains this anticlinal structure seems to be entirely overshadowed by the much more profound monoclinal movement, but eastward from the Alvord Valley faulting and tilting have not been so profound and the eastward divide of the basin seems to be determined by the crest of one of the original anticlines. To the south the basin reaches the less regular uplifts of the Pine Forest Mountains and Trident Peak. It is separated from the Black Rock Desert only by an alluvial divide across the Pueblo Valley, but this divide is nearly a thousand feet above the valley and is almost certainly pre-Lahontan. The northern extremity of the Alvord Valley is little known and it is possible that there may have been an outlet to the Malheur River, though the considerable salinity of the valley and the presence of old strand lines around it would indicate the contrary.

The present bottom of the valley is cut by alluvial divides into the subsidiary basins of Ten Cent, Juniper, Mann, Alvord, and Tum Tum Lakes and that of the Alvord Desert. All of these were covered and connected by the early lake and it is possible that most of the others drained into that of the Alvord Desert for some time after desiccation had begun. The White Horse Basin was also a former tributary and has been cut off by the accumulation of alluvium and dune sand in Sand Gap, through which it formerly discharged.

The Thousand Creek and Virgin Creek Valley lying on the lava plateau east of Long Valley, Nevada, seems to have been also a tributary of the Alvord and is now separated therefrom only by a low alluvial divide in the gap north of the Pine Forest Mountains. This valley has suffered greatly by stream decay and now contains numerous local playas of small area and very recent origin.

The areas of the various small basins into which the Alvord Valley is now divided have not been computed in detail. Their total area, exclusive of the White Horse Basin and the Thousand Creek Valley is about 1,600 square miles. The area of the White Horse Basin is about 300 square miles, and that of the Thousand Creek Valley 1,300 square miles, making a total of 3,200 square miles for the drainage area of the Alvord Basin during the Lahontan period.

THE GOOSE LAKE BASIN.

South of the Abert Basin, but without any certain structural relation thereto, is another north-south trough in which lies Goose Lake, between the Warner Mountains on the east and the Modoc lava plateau on the west. The southern portion of this valley is occupied and drained by the Pitt River, the northern, or Goose Lake portion, being separated therefrom only by an alluvial divide just south of the lake. This divide is apparently recent and is now only a few feet above the lake. It is probable that the lake has frequently overflowed it, and indeed it is reported that this has occasionally happened within the memory of present inhabitants. Undoubtedly the freshness of Goose Lake is to be thus explained.

THE MADELINE BASIN.

On the lava plateau north of the Honey Lake Basin is the very similar basin of the Madeline Plains. The structure of its walls is very irregular and in many places the divides are not exactly determinable. A number of low passes lead both to the Pitt River drainage and to the Honey Lake Basin, and some one of these may formerly have served as a channel of overflow. However, old strand lines are visible at several points about the basin and serve to indicate the existence and fluctuations of an inclosed lake. Until passes and strands have been studied more exactly and compared with each other it is impossible to read with any assurance the history of this ancient lake or to determine whether it overflowed or how long the overflow continued. Still less is it possible to decide whether the overflow, if any, was into the Pitt River or into Honey Lake.

The present floor of the valley is flat and featureless, except for occasional dune areas. There are many small local playas, but no area of general concentration is noted on the available maps or was observed by the writer. The plain is nowhere saline. At its southwestern corner an outlying tongue of the plain has been cut off by a low alluvial divide and forms the Grasshopper Valley. This valley was evidently once a part of the Madeline water body, but its subsequent relations thereto are uncertain. It now contains a small march. The total area of the Madeline Basin, including Grasshopper Valley, is about 900 square miles.

THE MODOC LAVA BEDS.

West and northwest of the Goose Lake Valley a series of great basalt flows stretches westward to the volcanic uplift which culminates in Mount Shasta. Diversified only by minor faults and folds and by a few deep and narrow canyons of erosion, the region has not developed any extensive drainage system and advancing desiccation has destroyed what little drainage there once was. The streams are dry and the occasional shallow depressions are areas of inclosed drainage floored by local playas. The region is not unlike that surrounding the Christmas Lake Valley as described on page 23, and, like it, has no importance to this inquiry. The small basins of the lava beds are so tiny and their inclosed condition is so recent that salt accumulation in them is practically out of the question. This applies also to the basin of Medicine Lake on the western edge of the area near Mount Hoffman, though it is not so fully desiccated as its analogues to the east.

THE KLAMATH LAKES.

On the northeastern border of the lava bed region are a series of shallow basins holding the Klamath Lakes. The geologic history of this region has not been studied in detail, but a brief examination of the major features has suggested to the writer that the present lakes probably occupy local depressions in the bed of a much larger lake, perhaps of late Tertiary age, which lake has been drained by the cutting of the gorge of the Klamath River. A similar history, on a smaller scale, is to be ascribed

to two tributaries of the Klamath group—the Klamath and Sycan Marshes. During the Lahontan period the whole of this region doubtless drained freely to the sea, but subsequent desiccation has so weakened its streams and increased fan-building that much of the area is now cut up into small basins and local saline playas. Even the large Tule Lake overflows only intermittently and several of the smaller lakes do not do so at all. All this, however, is quite recent and essentially the region has been and is one of seaward drainage.

THE TROUGH VALLEYS OF NEVADA AND THE BASINS OF THE TRANSITION ZONE.

The general character of these basins and their relations to the other divisions of the Great Basin were noted briefly on page 9. There is really no essential structural difference between them and those similar trough valleys which have chanced to drain to Lake Lahontan or to the Amargosa River, but this difference of drainage is quite important from the present viewpoint and makes desirable a separate treatment. The valleys of this division, though much alike in essentials of structure and topography, present an almost infinite variety of detail. It is obviously impossible to discuss them thoroughly, and the following statements are confined to a brief note of location and to those facts essential to the present inquiry.

THE DIXIE BASIN.

The Dixie or Osobb Valley occupies the first inclosed trough east of the Carson Sink. It now receives the drainage of the Pleasant Valley from the north and the Middle Gate and East Gate Valleys from the southeast. Neither of these drainage lines is now active, but both are freely open and are still traversed by the flood waters of heavy storms. The Fairview Valley to the south was probably once a tributary of the Dixie, but is now cut off by a low ridge the nature of which is not fully certain. The writer regards it as probably due to recent minor faulting, but possesses no conclusive evidence to this effect. Behind this barrier has been formed a small nonsaline playa known as Labou Flat.

The northern end of the Pleasant Valley is separated from the Humboldt Valley by a divide the present surface of which is alluvial, but this divide is high above the bottom of the Dixie Valley and the valley is believed never to have discharged in this direction or in any other. The greatest depression of the valley contains a mud flat nearly 60 square miles in area, in the center of which is a body of loosely crystallized common salt about 10 square miles in area and from 2 to 10 feet thick. This salt deposit is known as the Humboldt Salt Marsh and was once the source of commercial salt for metallurgical purposes. Old strand lines 150 feet and 40 feet above the present surface of the salt bed indicate the existence and fluctuations of the lake from which it was probably derived.

The area now permanently or occasionally tributary to the Dixie Valley is 2,000 square miles. The Fairview Valley has an area of 290 square miles, making a total of 2,290 square miles for the probable Dixie Valley of Lahontan time.

THE GABBS VALLEY.

Gabbs Valley lies southeast of that last described and is the northernmost of the small basins which constitute the transition zone. It is entirely surrounded by mountains of considerable height and has almost certainly never overflowed. It contains a saline flat with a sandy instead of a mud surface and about 25 square miles in area. There are no traces of an early lake. The total area of the basin is 1,280 square miles.

THE SODA SPRINGS TROUGH.

South of the Gabbs Valley and west of the Pilot Mountain Range is a short trough, now separated by alluvial divides into four small basins—the Acme, Luning, Mina, and Rhodes. Each basin contains a small playa, that of Rhodes being very saline, though the others are not especially so. The present areas are: Acme 130 square miles, Luning 175 square miles, Mina 65 square miles, and Rhodes 210 square miles, making a total of 580 square miles.

It is very difficult to guess the topography of this trough during the Lahontan period. Both divides and playas have been raised by post-Lahontan alluvial deposition and it may be either that the whole trough once drained into Rhodes or that it all, including Rhodes, drained northward into Walker Lake. The writer inclines to the opinion that the trough drained partly one way and partly the other, the Acme Basin being tributary to Walker Lake and the Luning and Mina Basins to Rhodes. If so, this may account for the greater salinity of the Rhodes playa, though the writer has been unable to discover any conclusive evidence of the existence of a Quaternary lake in this basin. On the assumption stated the Lahontan period drainage area of the Rhodes Basin would be 450 square miles. There is also a bare possibility that the Garfield Flat, next to be described, once drained into the Mina Basin and thence to the Rhodes. Including this and the Acme Basin, the Rhodes drainage area would be 670 square miles, which is a maximum value.

THE GARFIELD BASIN.

Just west of the Mina Basin and north of the main ridge of the Excelsior Mountains lies a small inclosed valley, the deepest depression of which is the Garfield Flat playa. The divide between this basin and the Mina Basin is in one place scarcely 150 feet above the playa and it is barely possible that there may once have been an outlet over or through this divide. The drainage area of the basin is but 90 square miles and this is believed far too small to have attained discharge over a divide of the present height, but the divide may formerly have been lower and subsequently raised by the deposition of alluvium. The question could probably be settled by careful study of the basin, but is unimportant, since the area is too small to give the basin any interest.

THE TEELS BASIN.

The Teels Basin lies directly south of the Garfield Basin. The lowest pass opens into the Rhodes Basin, but is over 800 feet above the floor and apparently never could have been a channel of overflow. Neither has the basin ever had any tributaries. The only chance of former inflow would be from the Huntoon Basin (described below) and the dividing pass is so high as to render this extremely improbable. The area of the basin is 320 square miles. In its deepest depression is the well-known Teels Salt Marsh, a playa of high salinity and which has unusual interest for the present inquiry because of the reported occurrence of hanksite and other saline minerals associated with the potash deposits at Searles Lake, California.

THE HUNTOON BASIN.

The Huntoon Basin is another basin quite similar to the Garfield and the Teels and lying west of the latter. The lowest pass leads into Teels, but since it is over 300 feet above the bottom, it is not considered probable that it was ever a line of discharge. The deepest depression contains a playa of the usual type, and not especially saline. The area of the basin is 115 square miles.



FIG. 1.—OLD DELTA OF HONEY CREEK, IN THE WARNER BASIN, OREG.

[A delta built into the Warner Lake during the Lahontan period and since much dissected by stream erosion.]



FIG. 2.—ANCIENT LAKE TERRACES ON THE EAST SIDE OF THE RAILROAD VALLEY, NEV.



FIG. 1.—SURFACE OF THE SALT BODY AT SEARLES LAKE, CAL.



FIG. 2.—CALCAREOUS TUFA COATING ON ROCKS 300 FEET ABOVE THE BOTTOM OF SEARLES LAKE BASIN, CAL., AND DEPOSITED BY THE WATERS OF THE ANCIENT LAKE.

THE MONTE CRISTO BASIN.

East of the Soda Springs Trough and surrounded by the Monte Cristo, Pilot, and Cedar Mountains, lies the Monte Cristo Basin. Its lowest divide is in the gap between the Cedar and Monte Cristo Mountains and is but little over 300 feet above the bottom of the valley. This divide is not alluvial, but there are some indications of recent movement and it is not impossible that this pass was once lower and the locus of an outflow into the Big Smoky Valley. The area of the basin is but 300 square miles, and, whether it overflowed or not, it is too small to be of great importance. Its deepest depression is now covered by loose blown sand.

THE COLUMBUS BASIN.

South of the Soda Springs Trough is the north-south trough of the Fish Lake Valley, all of which drains freely northward to the playa called the Columbus Salt Marsh and occupying the extreme northern end of the trough. The stream which occupied Fish Lake Valley has lost much of its vigor and a number of more or less saline marshes and playas have been left along its course. All of these are recent and unimportant. The lowest pass through which a discharge from the Columbus playa would be possible leads into Rhodes and the Soda Springs Trough, but the divide is nearly 500 feet above the playa, and there is little probability that discharge actually took place over it. The basin has almost certainly been an inclosed one during and since the Lahontan period. There is a system of strand lines of usual character, the highest about 150 feet above the flat. The present drainage area of the Columbus is quite small, but including the part of the Fish Lake Valley recently tributary to it, though now cut off, it equals 1,350 square miles. The Columbus playa is about 50 square miles in area.

THE CLAYTON OR SILVER PEAK BASIN.

The Clayton or Silver Peak Basin occupies a rather irregular structural depression just east of the Fish Lake Valley. Its lowest pass being 650 feet above its bottom, there is reasonable certainty that it never overflowed, though there is no satisfactory direct evidence that it formerly contained a lake. Its bottom is a very saline playa with many crusts and layers of common salt, both on the surface and in the clays below. The area of the playa is about 30 square miles and that of the basin about 550 square miles.

THE BIG SMOKY BASIN.

Eastward of Gabbs Valley and the southern end of the Dixie Valley lie three parallel north-and-south troughs, of which the outer two slope and drain southward, while the middle carries the northward-flowing stream of the Reese River. Toward the south the central trough and its limiting ranges pinch out and the two outer troughs merge into a much broader valley which continues to slope southward. These two outer troughs and their southward extension form the Big Smoky Basin. The whole has suffered greatly by stream decay, with the formation of many local playas and the cutting off by alluvial dams of the extremities of both of the northern troughs. The deepest depression of the basin is in the extreme southwest corner and is a playa of small salinity and somewhat diversified by small dune areas.

Just west of this playa between the Silver Peak and Monte Cristo Ranges is a pass scarcely 200 feet above the playa and leading into the Columbus Basin. The drainage area of the Big Smoky seems great enough to have filled the depression during the Lahontan period to a depth greater than 200 feet, but there is no evidence of discharge over this pass, and the highest of a system of lake terraces which surrounds the present playa is below the level of the pass. It is probable, therefore, that the Big Smoky did not overflow.

The area now tributary to the Big Smoky playa is probably not over 1,000 square miles, but the addition of the area to the north cut off by stream decay makes a total of 2,140 square mile. With the Kingston Basin, which was formerly tributary to it and is described below, the total area is 3,325 square miles, which was probably the drainage area of the valley during the Lahontan period.

THE KINGSTON BASIN.

The Kingston Basin occupies the northern tip of the eastern trough of the Big Smoky Basin, as above described. The separation from the Big Smoky is by an alluvial divide of uncertain age, but which the writer regards as recent. The floor of the basin carries a chain of local playas of greater or lesser size, lying along what was probably the old drainage line. These playas are separated from one another by alluvial divides mostly very low and inconspicuous. Their basins have not been individually traced or computed. The total area of the Kingston Basin, including all the local playas north of the main alluvial divide, is 1,190 square miles, all of which seems to have been formerly tributary to the Big Smoky Basin.

THE EDWARDS CREEK BASIN.

The Edwards Creek Basin lies east of the Dixie Basin above described and between the Clan Alpine Mountains on the west and the Desatoya-New Pass Range on the east. The surrounding divides are all well defined and mountainous, except at the south end. This southern divide, while superficially alluvial, seems to be fundamentally structural, and the writer regards it also as pre-Lahontan. The Edwards Creek Basin has probably long been landlocked.

The basin now receives the drainage of the northern end of the Smiths Creek Valley and it seems probable that it once received the entire drainage of this valley, as described below. The lowest depression is a playa about 15 square miles in area and not known to be especially saline. There are a few suggestions of old lake strands about the walls of the valley, but these are by no means unmistakable. The present drainage area of the basin is about 490 square miles. With the Smiths Creek basin the total is 990 square miles.

THE SMITHS CREEK BASIN.

The Smiths Creek Basin occupies the northern tip of the western trough of the Big Smoky Basin as described on page 33. Its past and even its present drainage relations are not certainly known. It seems that it is limited at both ends by alluvial divides. The southern of these is between 300 and 400 feet above the valley floor and forms the separation from the Ione Valley, a present tributary of the Big Smoky Basin. To the north the end of the valley is structurally defined, but the extreme north end of the structural trough drains westward through the narrow gap of New Pass Canyon and does not belong hydrographically to the Smiths Creek Basin. This northern end is separated from the main body of the Smiths Creek Valley by a low divide which the writer has not examined and concerning which no information is available. It is probable that it is low and alluvial and that the Smiths Creek Basin discharged over it and through New Pass Canyon into the Edwards Creek Basin above described. If this be true the playa, which now occupies about 23 square miles in the Smiths Creek Valley, must be of quite recent origin. The total present drainage area of the Smiths Creek Basin is about 500 square miles.

THE GOLDFIELD BASIN.

The Goldfield Basin lies west of the town of Goldfield and occupies what is structurally a southward extension of the eastern trough of the Big Smoky. It is cut off from the latter basin by an alluvial divide about 500 feet above the bottom of the

Goldfield Basin and about 600 feet above that of the Big Smoky. There is another divide at about the same elevation in a gap leading into the Clayton Basin. Both of these divides are believed to be pre-Lahontan and the Basin is thought to have been always inclosed. It has an area of 330 square miles and contains a small playa of usual character.

THE DIAMOND BASIN.

The Diamond Valley proper is a narrow north-south trough stretching north from Eureka, Nev., between the Sulphur Springs and Diamond Ranges. In itself it has an area of less than 1,000 square miles, but into its southwest corner discharges the remnant of a former great drainage system which drained the southern portion of the topographically poorly-defined region mentioned on page 16. The area of this drainage system aggregated 1,870 square miles and included the present Kobeh, Dry, and Monitor Valleys, the latter extending south to the north end of the Ralston Valley (Armagosa drainage system) near the old town of Belmont. Most of this drainage system is still essentially open, though never fully occupied by water. Storm waters occasionally fill part of it, but seem never to reach the Diamond Valley itself. In many places, especially in the southern end of the Monitor Valley, low and recent alluvial dams have been built and have caused the formation of local playas and marshes. None of these have any present importance.

The deepest depression of the Diamond Valley contains a very saline marsh or playa carrying a body of common salt of unknown extent and character. The lowest outward pass is Railroad Canyon at the northeast corner and leads into the Huntington River and thence to the Humboldt. This pass is now about 275 feet above the Diamond Valley salt marsh and it is uncertain whether it ever served as a channel of discharge. The writer inclines to the opinion that it did, but that the discharge was by overflow and occurred only during the maximum of the lake expansion. A long subsequent history as an independent valley seems very probable and is directly indicated by traces of old strand lines on the walls of the valley. In this report the valley is classed as landlocked and its area is not included in that of the Humboldt-Carson Basin.

The present drainage area tributary to the Diamond Valley playa is perhaps 900 square miles. The Lahontan period area was 2,800 square miles.

THE RAILROAD VALLEY.

The Railroad Valley is the largest of the inclosed troughs of Nevada and lies just southeast of the geographical center of the State, between the White Pine Range to the east and the Pancake Mountains to the west. The former range is one of the best defined of the Great Basin and, being high and continuous, it has formed a permanent divide between the Railroad Valley and the drainage of the Colorado River. The Pancake Mountains are much lower and less well defined and are crossed by several fairly low passes, through one of which (Twin Springs Pass) the Hot Creek Valley still drains into the Railroad Valley. West of the Hot Creek Valley is the Hot Creek Range, for the most part high and continuous, but cut about its middle by the canyon of the Hot Creek, through which comes the drainage of the southern portion of Fish Spring Valley, lying still farther west. The northern portion of this valley is now cut off by a low alluvial divide, but this is almost certainly very recent. Hot Creek Valley has also two other tributaries—part of the Little Smoky Valley from the north and part of the Reveille Valley from the south. The former is cut by an alluvial divide, north of which the drainage goes to the Gibson Valley, as discussed on page 17. This divide is believed to be pre-Lahontan and to have been a permanent parting between the Lahontan and Railroad Valley drainages. Reveille Valley is cut into three portions by two alluvial divides, the northern portion draining into the Hot Creek Valley, the southern portion into the Kawich (see p. 36), and the middle por-

tion eastward into the Railroad Valley proper. At its northern extremity the Railroad Valley proper is limited by an alluvial divide across the narrow Newark Valley; but this divide, though superficially alluvial, is really due to the general uplift of this region and is unquestionably pre-Lahontan. The southern extremity of the Railroad Valley is determined by the eastward bend of the Quinn Canyon Mountains (White Pine Range) to join the Reveille Range, which is the southward extension of the Pancakes. It is probable that the Penoyer Valley, lying south of this divide, was once a tributary of the Railroad Valley, but this will be discussed below.

The present deepest depression of the Railroad Valley lies rather north of its center and is a typical playa about 80 square miles in area and not unusually saline. South of this are a large number of smaller playas determined by recent alluvial divides and receiving the drainage of their immediate surroundings only. One of these, lying south of the Twin Springs Pass, is of considerable size and is separated from the main valley by a fairly high divide due mainly to the fan built eastward by the Hot Creek Valley discharge as it leaves the Twin Springs Pass. This divide may be of considerable antiquity and the basin behind it may have had a significant independent history. It is, however, the writer's opinion that both divide and basin are post-Lahontan. Some of these southern playas are of considerable salinity and about the north end of the main playa are a number of small pans apparently caused by previous dune accumulations and which are also quite saline. The salts of some of these pans contain significant proportions of potassium and the Railroad Valley Company of Tonopah is now (1912) drilling at the north end of the main playa in the hope of finding buried deposits of potassium salts.

Hot Creek Valley and its tributaries have suffered less from alluvial damming than has Railroad Valley proper. The channel which traverses it is still open, though seldom occupied, and no significant areas of local concentration are known. A small stream apparently derived from the Hot Creek Valley underflow traverses the Twin Springs Pass, but does not reach the main Railroad Valley playa.

There can be no doubt of the permanently inclosed character of the Railroad Valley, and a series of old strand lines and wave bars witnesses its former occupation by a persistent lake. (Pl. IV, fig. 2.) The highest of these strands is 155 feet by aneroid above the main playa.

The area now tributary to the main playa is perhaps 2,000 square miles. Including Hot Creek Valley and its present tributaries and all the playas of the Railroad Valley proper, the area is 4,555 square miles. Fish Spring Valley adds 415 square miles, making a total of 4,970 square miles which is reasonably certain to have been tributary to the valley during the Lahontan period. With the Kawich and Penoyer Valleys, which were probably though not certainly once tributary, the total drainage area would be 6,340 square miles. This is a maximum value.

THE KAWICH BASIN.

The Kawich Valley has already been noted as lying south of the Reveille Valley and separated therefrom only by an alluvial divide. This divide is now about 400 feet above the bottom of the valley, but has probably been considerably raised by recently added alluvium. The writer is of the opinion that it is post-Lahontan and that the Lahontan period drainage of the Kawich was north, through the middle portion of the Reveille Valley, and thence northeast into the Railroad Valley. The present floor of the Kawich Valley is a flat on which are a number of playas of the usual character. The area of the basin is 370 square miles.

THE PENOYER BASIN.

The Penoyer Valley lies south of the Railroad Valley proper and is believed to be separated therefrom only by an alluvial divide of recent origin. However, the maps of the region are very inadequate and the writer's personal examinations have not

been sufficiently thorough to warrant a decided opinion. The bottom of the valley is known to carry a playa, but its nature is unknown. The basin area is about 1,000 square miles.

THE GOLD FLAT BASIN.

Gold Flat lies west of the Kawich Basin and below the northern slope of the Pahute Mesa. Its lowest side is toward the north and is never less than 600 feet above the flat. The topography is such that it can not be considered entirely impossible for this north boundary to be due to recent alluvial accumulation, but it does not seem probable. The writer is of the opinion that the inclosed character of the basin is pre-Lahontan. The flat carries one playa about 3 square miles in area and several smaller ones. The basin area is 640 square miles.

THE EMIGRANT BASIN.

The Emigrant or Timpahute Valley lies south and southeast of the Penoyer Basin. No satisfactory maps of it are available, and it has not been visited by the writer. Nearly everything concerning it is uncertain, but it is believed to be inclosed by permanent divides and to have a drainage area of about 800 square miles, concentrating in a playa about 10 square miles in area. There is, however, great uncertainty as to the position of the divide between it and the Pintwater Basin (see below), and the actual drainage area may be as large as 1,000 square miles or as small as 400 square miles. It is more likely to be smaller than larger than the figure of 800 square miles given above.

THE YUCCA BASIN.

The Yucca Basin lies directly southwest of the Emigrant Valley. Little is known concerning it, but it is separated from the Frenchman Flat Basin to the south by an alluvial divide less than 100 feet high and is believed to have been tributary thereto. It now contains a small playa. The basin area is slightly less than 300 square miles.

THE FRENCHMAN FLAT BASIN.

Frenchman Flat lies south of the Yucca Basin in the depression within the crescent of the Spotted Range. There is a pass about 500 feet high opening into the Amargosa Valley, but this divide, though partly alluvial, is believed to be pre-Lahontan. The basin has probably been permanently inclosed. It contains a typical playa. Alone, the area of the basin is about 450 square miles, but including the Yucca Basin (see above), which was probably once a tributary, the area is about 740 square miles.

THE INDIAN SPRING BASIN.

The Indian Spring Valley is a north-south trough lying east of the Frenchman Flat Basin and between the Spotted and Pintwater Ranges. It is separated from the Lee Canyon Basin by a divide only 130 feet high. This divide is alluvial and almost certainly recent and there is little doubt that the basin once drained into the Lee Canyon Basin and thence to the Las Vegas Valley and the Colorado River. The area of the present basin is 650 square miles.

THE PINTWATER BASIN.

The Pintwater or Desert Valley is a trough similar to that of the Indian Spring Valley and lying east of it. At its south end it is separated from the Lee Canyon Basin by a recent alluvial divide only a few feet high. There is no doubt that the basin was very recently a part of the Colorado drainage. The area of the basin is estimated at 730 square miles, but the position of the northern boundary is very uncertain and this area is a very rough approximation.

THE LEE CANYON BASIN.

The Lee Canyon Basin is of very recent origin, occupying the northwestern end of the Las Vegas Valley, being separated from the main drainage of that valley by a divide less than 15 feet high. It was once the channel of the drainage of the Pintwater and Indian Spring Basins, as above noted. Because of its recency the basin has no importance to the present inquiry. Its area is 300 square miles.

THE SHEEP RANGE BASIN.

The Sheep Range Basin lies between the Sheep and Desert Ranges and east of the Pintwater Basin. Its northern third has never been mapped and is almost unknown. It may have drained into the Pintwater or directly into the Colorado drainage, or it may have been always inclosed. In any case, its small area of less than 300 square miles renders it unimportant.

THE SPRING VALLEY BASIN.

The Spring Valley is a trough valley of regular and normal type lying east of the southern part of the Steptoe Valley (see p. 20) and parallel thereto. Its northern end has never been mapped accurately and has not been visited by the writer. It is considered probable that the valley once drained either northward into the Goshute Basin or northwestward into the basin of the Great Salt Lake, but it can not be said definitely that this is the case. The area of the basin is about 1,550 square miles, this area being somewhat approximate, owing to uncertainty as to the position and nature of the northern boundary.

THE DESERT VALLEY DRY LAKES.

In the Desert Valley, southwest of the town of Pioche, Nev., is a group of small playas or "dry lakes." These playas and the trough in which they lie were very recently tributary to the Colorado River drainage and are now cut off therefrom only by low alluvial divides. Neither they nor their basin has any importance from the present point of view.

THE GANNETT BASIN.

Near the station of Gannett, east of Las Vegas, on the San Pedro, Los Angeles & Salt Lake Railway, a former tributary of Muddy Creek has been dammed by alluvium with the formation of a small and shallow basin of very recent origin. Its drainage area is less than 150 square miles and both this small size and its recent origin render it of no importance.

THE OPAL MOUNTAIN BASIN.

The Opal Mountain Basin lies in an isolated trough between the McCollough Range and the Opal or Eldorado Range in the extreme southern corner of Nevada. It appears to be mainly structural and those divides which are superficially alluvial are high and probably ancient. The writer is inclined to regard the basin as pre-Lahontan, but has never visited it and can not advance a decided opinion. If overflow ever did occur it was unquestionably into the Colorado River. The area of the basin is 580 square miles. It contains a playa of unknown area and character.

THE TROUGH VALLEYS OF CALIFORNIA AND THE MOJAVE DESERT.

South of the Lahontan Basin, the western boundary of the Great Basin is still the crest of the Sierra Nevada, which continues to run nearly north and south until just north of the thirty-fifth parallel, where the Sierras bend slightly westward to form the lower and more diffuse Tehachapi Mountains. These merge to the south into another

main uplift, that of the San Bernardino Mountains, but the trend is here northwest and southeast, instead of north and south.

These trends of the basin boundary are paralleled by the troughs within it. In the northern part of this division are four great troughs running very nearly north and south and hence parallel to the Sierra. In the southern portion are two similar troughs, but running northwest and southeast in parallelism to the crest of the San Bernardino. Between the two sets of troughs is a considerable area of more complex structure and less pronounced relief. Of the northern troughs the westernmost, under the crest of the Sierra, contains the Owens Valley, with the Mono and Searles Basins to the north and south, respectively. The next trough to the east is the Panamint Valley, with what are essentially its northern extensions in the Saline, Eureka, and Deep Springs Valleys. The third trough is that of Death Valley, and the fourth and last is that of the Amargosa Valley, with the Pahrump and Ivanpah Valleys cut off from its southern end. The intermediate zone of less concentrated uplift is mainly drained by the Mojave River, though the Kane, Willard, Granite Mountain, and Owl Basins lie within it and seem to have been permanently undrained. The two southern troughs parallel to the San Bernardino belong partly by the Mojave drainage and partly to the former drainage of the Colorado River, being cut by alluvial divides in the same manner as the trough valleys of Nevada south and east of the Lahontan Basin.

THE MONO BASIN.

The Mono Basin is here classed as belonging to the westernmost or Owens Valley trough of this division, but its structural affiliations are quite as close with the basins of the Nevada transition zone and the classification adopted is entirely arbitrary. It occupies a structural depression of considerable depth, contains the saline Mono Lake, and has always been without outlet. The Quaternary history of the basin has been studied by Russell,¹ to whose report the reader is referred for details. One part of the structural basin, the Aurora Basin, is now cut off from the valley of Mono Lake by a divide nearly 300 feet high, but this divide was below the waters of the greater lake which occupied the valley during the Lahontan period, and the independent history of the Aurora Basin is post-Lahontan only. The area of the present Mono Basin is 675 square miles. With the Aurora Basin, the total is 770 square miles.

THE OWENS BASIN.

The Owens Valley occupies the central and largest portion of the trough just east of the Sierra. Its general slope is southward and it is occupied for most of its length by the Owens River, which empties into Owens Lake at the southern extremity of the valley. South of the lake is an alluvial divide only 166 feet above the present surface of the lake. This divide is apparently of some antiquity, but it is considered practically certain that the lake overflowed it during the Lahontan period and discharged southward into the Searles Basin described below. The independent history of the Owens Basin is therefore comparatively short, and the considerable salinity of Owens Lake acquires unusual interest for the interpretation of the geochemical history of the Great Basin.

¹ U. S. Geol. Sur., 8th Annual Report, Part I, pp. 261-394 (1889).

At its northern end Owens Valley now receives the drainage of Long Valley, and doubtless once received that of Adobe Valley, now a region of several local depressions. Except for the loss of Adobe Valley the basin has suffered very little by stream decay, having been saved by its proximity to the Sierra. The present area of the Owens Basin is 2,550 square miles; with the Adobe Valley it is 2,825 square miles.

THE SEARLES BASIN.

The Searles Basin lies directly south of the Owens, and the greater portion of its area is a direct continuation of the Owens Valley trough. The deepest depression, however, lies eastward beyond the Argus Range, which is here cut by a narrow canyon of erosion—Salt Wells Canyon. This deepest depression is the so-called Searles Lake. The tributary area to the west is known in various parts as the Indian Wells, China Lake, and Salt Wells Valleys. The bottom of the Searles depression is a body of white crystalline salts almost 12 square miles in area and with a maximum depth of about 75 feet. (Pl. V, fig. 1.) Under this are saline muds and sands, sometimes more or less cemented. The salts are mainly the chloride, carbonate, and sulphate of sodium, with lesser amounts of borax and of salts of potassium, the latter being largely in the brine which saturates the salt body. The potassium and other salts are believed to be very valuable commercially, and preparations are now under way for their exploitation.

The Salt Wells Canyon is pre-Lahontan, but the lake which occupied Searles during the Lahontan period stood a little over 600 feet above the present salt flat and extended through this canyon and a considerable way into the valley to the west. Both then and since this latter valley has acted as a settling basin for alluvium, and this is believed to have much to do with the exceptional purity of the Searles salt body. A series of old lake and estuarine beds clinging to the walls of Salt Wells Canyon records a period of some length during which the lake stood at a moderate elevation, perhaps 300 feet above the present surface, and permitted the partial filling of the canyon, which was then an estuary. This same intermediate level and several others, both above and below it, are recorded in a complex series of lake terraces, tufa deposits, etc., which surround the basin. (Pl. V, fig. 2.) These relicts of the ancient lake have suffered much more by erosion than have the similar records of Lakes Lahontan and Bonneville, but the significance of this fact is yet obscure.

It will be recalled that the Owens Valley probably once overflowed into Searles through the Salt Wells Valley, and it is quite possible that Searles itself had a period of overflow. The highest of the lake strands about the basin is a trifle over 600 feet above the floor and the divide at the southern end of the basin between it and the drainage of the Panamint is at very nearly the same elevation. It is possible that the lake spilled for a time over this divide into the Panamint. The question could doubtless be settled by a careful study of this divide and the approaches to it, but the study has not been made, and it is not now possible to be certain. In any case, the lake can hardly have overflowed for long, since the divide is not an alluvial dam, and, if anything, has probably been lowered rather than raised by post-Lahontan rain-wash. Furthermore, the series of terraces below the divide indicates a long and varied independent existence of the lake, and the absence of tufa on or near the highest terrace suggests that when the lake did overflow (if it did) it was essentially fresh.

At the present time the tributary valley west of Searles has suffered greatly by stream decay and has come to contain a large number of more or less local playas, the most important of which is China Lake. All these are shallow and recent and would again become tributary to Searles if the rainfall were to increase only very slightly. Including them and the whole of its present tributaries the area of the basin is 2,030 square miles. With the entire Owens Basin the area is 4,850 square miles, which almost certainly represents its area during the Lahontan period.

THE PANAMINT BASIN.

The Panamint Valley occupies the southern portion of the trough east of that of the Owens Valley, being the second trough east of the Sierra. It has two tributary valleys, the Leach Valley in the southeast corner and a part of the Coso Valley to the northwest, from both of which the drainage is still entirely open. The floor of the Panamint is divided by a low alluvial divide into two sections, each of which contains a playa, the northern one having a present or very recent drainage into the southern. Both of these playas are saline, the southern one especially so. Stream decay has also produced a number of small local playas in both ends of the valley, all of which are recent and unimportant.

The most interesting feature in the topography of the Panamint is the possible former drainage from the Searles Basin, as discussed above. However, as there noted, this inflow was at most very brief and has probably not affected very greatly the geochemical history of the valley. Excepting the pass into Searles all outlets from the Panamint are high and all are far above any possible lake level. The history of the valley has been essentially one of independence. The present drainage areas of the various playas are impossible of accurate estimation. Very seldom is there any drainage at all. The total area of the basin is 1,950 square miles, including all tributaries except Searles. Including Searles and Owens the area would be 6,800 square miles, but it must be remembered that this greater area was tributary to the Panamint only very transiently, if at all.

THE SALINE VALLEY.

The Saline Valley occupies what is essentially a northern extension of the Panamint trough, though cut off therefrom by a prominent cross uplift. The basin is entirely surrounded by high structural divides, the lowest pass being nearly 4,000 feet above the deepest depression. There is no possibility of overflow since the basin has had its present structure. In the southeast corner of the basin are two small subsidiary basins, previously tributary, but now cut off by stream decay and alluvial damming. One of these contains a playa known as the Racetrack. The other contains a very small playa unnamed. The deepest depression of the Saline Basin is occupied by a very saline playa having an area of about 12 square miles and carrying a deposit of common salt, the commercial exploitation of which is now being attempted. The area of the basin, including the small subsidiary basins above mentioned, is 845 square miles.

THE EUREKA BASIN.

The Eureka Basin lies just north of the Saline Valley (last discussed) and is very similar thereto, except that the only playa it contains is small and not saline. The lowest pass is over 2,000 feet above the present bottom, all divides are structural and ancient, and there is no possibility of overflow during or since the Lahontan period. This basin and the Saline Valley are perhaps the best and simplest known examples of the inclosed basin of structural origin, and would probably well repay careful scientific study.

Cowhorn Valley, in the mountains west of the Eureka Basin, is now cut off behind a low alluvial divide, but was formerly tributary. Including this, the area of the Eureka Basin is 590 square miles. It is probable that the Deep Springs Valley (next below) was also tributary to the Eureka during Lahontan time. Including it, the total area is 775 square miles.

THE DEEP SPRINGS VALLEY.

West of the northern end of the Eureka Valley lies the similar, though smaller, basin of the Deep Springs Valley. In the main, the surrounding divides are high and structural, but the eastern wall of the basin is breached by the narrow canyon of Soldier

Pass, opening into the Eureka Basin. The present divide in this canyon is over 400 feet above the bottom of the Deep Springs Valley, but has probably been raised to some extent by post-Lahontan alluvium. It is not possible to be certain that this canyon ever served as a line of discharge, but the writer considers it probable that it did, especially since the basin drains high and well-watered mountain slopes on which the Lahontan period rainfall must have been quite high. It is probable, therefore, that the basin was once tributary to the Eureka Basin. The drainage area of the Deep Springs Valley is 185 square miles. It contains a small variable lake, fed largely by springs.

THE KANE BASIN.

Mention has already been made of the zone of less concentrated uplift which lies south of the great north and south troughs of Owens, the Panamint, Death Valley, and the Amargosa. Of the four permanent basins which the zone contains, the largest and westernmost is that of Kane Lake. It lies immediately south of Searles and might be considered a part of the Owens-Searles trough, being separated therefrom by the cross uplift of the El Paso Mountains. The southeastern divide of the basin runs across a region of less definite topography bordering the Mojave Desert, and is frequently inconspicuous. It is possible that the basin once discharged over some undetermined point on this quarter of its rim, but the general difference in elevation between rim and flat is about 600 feet and discharge is not considered probable. The present bottom of the basin is a playa with an area of about 15 square miles and having a considerable salinity. There are also several local playas north, east, and southeast of the main playa, but all are recent and unimportant. Into the southwest corner of the basin opens the high Tehachapi Valley, on the crest of the mountains of that name. Stream decay and alluvial damming have cut off a portion of this valley, with the formation of a local playa of little antiquity and slight importance. The area of the Kane Basin, including the Tehachapi Valley, is approximately 900 square miles, a moderate possible error being introduced by uncertainty as to the exact position of the southeastern divide.

THE WILLARD BASIN.

The Willard Basin is a small basin lying just east of the Kane and not unlike it. The divide which separates it from the Mojave drainage is neither well defined nor well known, and previous outflow is distinctly a possibility. The deepest depression is occupied by the playa of Willard Lake, which offers no exceptional features. The basin area is somewhat uncertain, because of lack of exact knowledge of the divides, but is certainly less than 250 square miles.

THE GRANITE MOUNTAIN BASIN.

The Granite Mountain Basin is a small structural basin south of the Leach Valley extension of the Panamint and between the Leach and Granite Mountains. It is little known, but is believed to be entirely surrounded by high and permanent divides. Its floor carries several playa areas, the mutual relations of which are unknown. The basin area is 150 square miles.

THE OWL BASIN.

The easternmost and smallest of the four permanent basins of the transition group is a tiny mountain valley just south of Death Valley and which contains the Owl Lake playa. It has never been mapped or scientifically studied, and its nature is almost entirely unknown. Its inclosed condition is believed to be structural and pre-Lahontan, but a previous drainage into Death Valley is not impossible. In any case its area of less than 60 square miles makes it of little importance.

THE DEATH VALLEY BASIN.

East of the Panamint trough lies the great trough of Death Valley, the deepest depression on the continent and with its tributary drainage, the third of the three greater divisions of the Great Basin, the other two being Bonneville and Lahontan. In itself the trough of Death Valley is not especially large, nor is it exceptional for anything except depth. It derives its unusual interest to the present inquiry from the fact that it at present receives the drainage of the Amargosa River and but recently received that of the Mojave River as well. These river systems are briefly described in the two following sections. It is sufficient here to note that they entered the Death Valley trough at its southern extremity through a common channel.

The floor of Death Valley is an immense playa occasionally constricted but not broken by tongues of alluvium pushed outward from the mountains. (Pl. VI, fig. 1.) This playa is very nearly of one level, but there is apparently a very shallow depression close to the eastern wall of the valley, northeast of Bennetts Wells, and which is usually occupied by a shallow lake of saturated brine. Wet-weather drainage lines reach this sink both from the north and south, the latter carrying what remains of the water of the Amargosa. The whole playa is extremely saline, much of it is constantly moist and muddy, and all ground waters are nearly saturated brines. In places on the playa common salt has crystallized in the surface clays in such a way as to form a broken crust or "salt reef" not unlike in appearance the "ice pillars" produced by frost in moist clay soils (Plate VI, fig. 2). The irregularities of this broken crust have sometimes an altitude of several feet and are quite without parallel in North America, though Dr. Ellsworth Huntington informs the writer that similar forms occur on the salt desert of Lob Nor in central Asia. The north arm of Death Valley contains a playa-like flat which is comparatively nonsaline and has a present drainage southward. All other tributaries are mountain streams of usual type.

The most interesting question concerning the Death Valley depression is that of its age. The Panamint Range, which forms its western boundary, is unquestionably ancient and the great apron which fringes its valleyward slope seems also to be very old. But the Funeral Mountains to the east are apparently much more recent, beds of apparently Tertiary age are prominent within them, and it is quite possible that they and the present topography of the valley originated quite within the period we are discussing. Neither space nor available data permit the discussion of this question in detail. It must suffice for the writer to express his personal opinion that this movement though mainly post-Tertiary and probably still in progress, is essentially pre-Lahontan and has not affected the fundamentals of the valley topography.

The drainage area now tributary to the Death Valley flat, including that part of the Amargosa where the channel is still unclogged, is very nearly 7,970 square miles. The cut-off portions of the Amargosa drainage add an additional 5,430 square miles, and the Mojave drainage, past and present, aggregates 10,160 square miles, making a grand total of 23,560 square miles in the entire Lahontan period basin.

AMARGOSA DRAINAGE SYSTEM.

The main trunk of the Amargosa River occupies the fourth and easternmost of the system of troughs parallel to the Sierra Nevada. In Lahontan times its remotest tributaries headed far north in the trough valleys of Nevada, touching the fringe of the Lahontan drainage at the divides which head the branches of the Ralston Valley. The tributaries from these two branches were joined a little to the south by a third flowing westward from Cactus Flat and the augmented stream continued southward west of Stonewall Mountain and the Pahute Mesa, across the Sarcobatus Flat and through a narrow pass in the Bullfrog Hills into the Amargosa Desert and the valley still followed by the river. Somewhat north of the thirty-sixth parallel the great trough divides, its main branch rising southeastward toward the Pahrump and Ivanpah Valleys, practi-

cally parallel with the Nevada-California line, while a lesser though deeper branch diverges a little to the west between the great Amargosa Range on the west and the Resting Springs and Kingston Mountains on the east.

It was this western branch which was followed by the Amargosa River, the eastern trough being occupied by a northward-flowing tributary which joined the greater river near what is now the station of Death Valley Junction on the Tonopah & Tidewater Railroad. Just north of the Avawatz Mountains the Amargosa was joined by the Mojave and the united river turned sharply to the west through an apparently structural pass between the Avawatz Range and the south end of the Amargosa Mountains, thus entering the southern end of the Death Valley depression. This Quaternary Amargosa was a river of no small proportions beside which its present descendant is indeed puny. Stream decay and the building of alluvial dams have robbed it of over half its length and nearly three-fourths of its drainage area, and the former great valley is cut into a multitude of shallow basins and local playas, each with its tiny tributaries and its "alkali" flat. At the northern end of the Ralston Valley an area of nearly 1,750 square miles has been cut off by an alluvial divide about 150 feet high, itself losing its former tributary from Cactus Flat. Next southward a segment of the early valley has been cut off to form the basin of Stonewall Flat, while just beyond, under the shadow of Stonewall Mountain, lie two other playas, and westward in the formerly tributary valley between Jackson and Montezuma Peaks lies a third, all now cut off behind recent alluvial divides. From these basins south to the Bullfrog Hills is the basin of Sarcobatus Flat, with an area of nearly 800 square miles and carrying besides its main playa many smaller and more local ones, and several once tributary valleys now cut off to form small basins. Once this flat discharged southward through a valley north of the Bullfrog Hills, but this is now closed by two alluvial divides with a small inclosed basin between. Southward of this divide the channel of the Amargosa proper is still essentially clear, though many more or less local playas and saline flats have been left along the filled floor of the trough and in small tributary valleys. However, another considerable tributary has been lost by the cutting off of over 1,400 square miles of the eastward-trending trough already noticed and which now forms the Pahrump Basin. Alluvial divides have not only cut this valley from the main drainage, but have split it into three parts, the Stewart Valley to the north, the Pahrump Valley proper in the middle, and the Mesquite Valley at the south. The divide which bars the latter is of considerable elevation and may conceivably be pre-Lahontan. If so the basin belongs to the class of the permanently inclosed, but the writer does not incline to this opinion and prefers to regard it as formerly a part of the Amargosa. South of the Pahrump lies the Ivanpah Basin, but this is probably pre-Lahontan and is separately discussed on page 45.

The mutilation of the Amargosa, though due essentially to aridity and stream decay, may quite possibly have been affected favorably or unfavorably by local and recent movement. The detailed history of the valley is extremely complex and, though as interesting as it is intricate, is scarcely germane to the present study. Apparently both Tertiary and Quaternary have seen a chain of lake basins, whose alternate filling and cutting has gone on under the complex interaction of frequent though moderate movement and of continuous and complicated climatic change. These changes have been incessant and are still in progress, but it is not believed that during or since the Lahontan period they have affected the essentials of the topography or caused the persistent concentration of drainage elsewhere than in the Death Valley sink.

The area of the Amargosa drainage is given in connection with Death Valley on page 43.

THE MOJAVE DRAINAGE SYSTEM.

The Amargosa was and is essentially a single stream occupying a long, narrow trough. The Quaternary Mojave was more dendritic. Rising in the northern slopes of San Bernardino Peak, it cut, like the Humboldt, directly across the main structural features of the region, entered at Soda Lake a north-south trough which is perhaps related to that of the Amargosa, and followed this north to the junction with the Amargosa and the western turn into Death Valley. How far this course was determined by the structure of the country and how far it was anterior to and imposed upon it, it is impossible to say. The writer is strongly inclined to consider it largely the latter. In any case, from each trough that it cut and each plain that it tapped it received its greater or lesser tributaries each with its own dendritic drainage, or perhaps its chain of lakes. All of this is now changed. Perhaps more than any other American area the Mojave Desert shows the effects of lessened rainfall. It is a country where lakes are dead and streams are dying and where only the occasional arroyos galvanized into vigor by rare and sudden storms maintain the semblance of a drainage. The Mojave River has lost all its tributaries, and its main stream, though fed by the well-watered slopes of San Bernardino Peak, flows no farther than Soda Lake and seldom even so far. Dams of dune sand and alluvium have blocked the greater valleys and cut the flatter areas into a checkerboard of minor basins. "Dry lakes" lie in nearly every township. Indeed, so numerous are they that the writer possesses authentic information concerning nearly 50 of them. It would scarcely be profitable to review all of these in detail. Larger or smaller, relatively old or relatively young, all were once part of the Mojave and all are post-Lahontan. Rodriguez, Rosamond, Rabbit, and Harper Lakes in the west, and Coyote, Coolgardie, Cronese, Garlic, and Langford Lakes to the north, are among the most important and all are of the same type.

Some of the larger and older playas are somewhat saline, but this salinity is recent and superficial. Even in Soda Lake, which is the present terminus of the Mojave River, waters a score of feet under the surface are practically fresh. North of Soda Lake there is a river channel, but no river. Local rainfall and an occasional brief overflow from Soda Lake have created a small playa at Silver Lake, about 20 miles north. North of this is a dam of recent dune sand and then the valley of the Amargosa and free drainage into Death Valley.

It has been considered useless to compute the area of the various basins into which the Mojave drainage has been divided. The total is 10,160 square miles.

THE IVANPAH BASIN.

The Ivanpah Valley lies in the extreme southern end of that offshoot of the Amargosa trough which carries the Pahrump Basin (see p. 44). However, the divide which separates it from this trough is high and structural, as are all the other divides which limit the basin. It is practically certain that its inclosed and independent condition is both ancient and permanent. The bottom of the valley now contains two playas of usual character and separated by a very low alluvial divide. There are also in the northeastern end of the basin two small basins and playas, now independent but believed once to have been tributary either by free drainage or by overflow, probably the latter. The total basin area is 900 square miles.

THE MESQUITE TROUGH.

Mention has already been made of the two structural troughs which lie north of and parallel to the San Bernardino Mountains. The southernmost of these is structurally continuous and open from the Mojave Desert to the Colorado River, but, like the similar troughs of central Nevada, it is higher in the center than at the extremities,

this elevation determining a water parting, which is superficially alluvial but nevertheless quite ancient. This divide crosses the trough in the neighborhood of Wilburs Well, located by the surveys of the General Land Office in township 3 north, range 5 east, San Bernardino base and meridian. West of this point the trough was once a tributary of the Mojave, and now contains a series of playas due to this tributary's decay. East of the divide the trough once drained to the Colorado River, but alluvial damming has now cut it into a half dozen basins each independent and inclosed and each with its typical playa. It has not been considered necessary to attempt the delineation and study of each of these local basins in detail. The most important are those of Mesquite, Dale, and Palen Lakes. The exact heights of the various divides are unknown, but all are believed to be recent and the basins they form are thought to have belonged quite recently to the Colorado drainage and to have, therefore, slight importance to the present inquiry. The total area of present inclosed drainage in this trough and east of the Wilburs Well divide is 3,520 square miles.

THE BRISTOL TROUGH.

The second trough north of the San Bernardino Mountains is occupied by the basins of Bristol, Cadiz, and Danby Lakes, the first receiving also the drainage of a high valley running toward the northeast between the Providence and Piute (or Pahute) Ranges. The exact interrelations of these lakes and their basins are not fully known, but they are believed to be analogous to those of the trough last discussed, and to have drained quite recently into the Colorado River. The divide between the westernmost or Bristol Basin and the Mojave is the local uplift of Ash Hill and is believed to have originated in connection with a center of recent vulcanism a little to the west. This divide, though of no considerable antiquity, is believed to be pre-Lahontan. The only chance of importance of these basins to the present inquiry lies in the possibility that one or more of them may have been inclosed longer than is assumed and may have been an area of salt accumulation during a considerable period. The surveys of the region are so few and so inaccurate that this possibility can not be absolutely denied; though it is believed to be remote. Danby Lake is known to contain a considerable deposit of common salt, but this is believed to be of recent and secondary origin. The total area of the basins of all three lakes is approximately 4,150 square miles.

THE SALTON BASIN.

South of and parallel to the San Bernardino Range is another structural trough similar to those north of it but deeper, and open southward to the Gulf of California. This trough is now cut off from the Gulf by a low divide of alluvial material and its deepest depression is occupied by the Salton Sea, the surface of which is over 200 feet below sea level. W. P. Blake, who made the first scientific examination of the basin¹ and discovered its negative elevation, concluded that the trough had once contained an arm of the sea and had been cut off by the gradual out-building of the delta of the Colorado River from the eastern shore. The delta having been built above the water level, the river might have flowed northward into the basin or southward into the Gulf. As a matter of fact it has done both. Being an alluvial river of very variable bed, it has flowed alternately to the basin and to the Gulf, probably many times in each direction. The present Salton Sea was created by an accidental

¹ Pacific Railway Reports, Vol. 5 (1856).

turning of the river toward the basin in 1905 and 1906, a condition which it cost millions to remedy. Had no attempt been made to return the river to its seaward bed, or had this attempt been unsuccessful, the basin would have filled until it overflowed into the Gulf or until the Colorado turned southward of its own accord. In either case desertion by the river would have left an inclosed sea to slowly evaporate as the Salton Sea is now doing. That this history was actually enacted in the recent past is indicated by a deeply cut old beach line surrounding the basin at about 40 feet above sea level and a series of lesser and lower strands marking stages of retreat. The similarity of conditions then and now is attested by the fact that this older series of strands can not be distinguished from the strands which have been formed by the retreat of the present Salton Sea.

This interpretation of the recent history of the Salton Basin may require modification in detail. For instance, there has been some degree of post-Tertiary movement along the north side of the basin, and the exposed beds have been found to contain saline strata which exactly simulate beds deposited in continental inclosed lakes or playas. It is difficult to reconcile this with the hypothesis of long marine occupation of the trough. In this and other directions Dr. Blake's theory may need revision, but its essentials will probably stand. In any case, it is apparent that both the topography and the history of the Salton have been very different from that of the basins previously discussed. The major factor has been, not varying climate but a vagrant Colorado. This difference of history makes the usual criteria of little value.

The size and nature of the drainage basin, its mutilation by stream decay, the probabilities of inflow or overflow, are here of little importance. Of course, salt accumulation is quite possible either by the evaporation of marine water, the assistance of the river, or the ordinary continental processes, but the problem is in no case one of topography and is therefore beyond the scope of the present paper.

A word should perhaps be devoted to the delta of the Colorado.¹ This is a broad, alluvial plain, of no visible relief, and traversed by a network of bayous. The position occupied by the divide between gulf and basin is entirely indeterminate, and there is no rainfall to develop it. The lower channel of the Colorado is exceedingly variable and the delta is dotted with lakes and marshes, which are souvenirs of its presence. So far as known, all of these are essentially fresh, except some small ponds near the so-called Volcano Lake, and the salinity of these is due to recent and present fumarole activity. One of the lakes contains a considerable percentage of potash alum, which will doubtless be developed when transportation and political condi-

¹ For information concerning the delta I am indebted mainly to the papers of Dr. D. T. MacDougal and to personal communication from him.

tions become sufficiently favorable. Down the west side of the delta runs the so-called Rio Hardy or Hardy Colorado, which is fed by seepages or direct channels from the larger river to the east. West of the Cocopa Mountains and close to this Rio Hardy is a shallow basin separated from the river only by a wide and flat plain of very little elevation. In times of flood the Hardy sometimes covers this plain and fills the depression. On the retreat of the river there is formed an inclosed lake known as Laguna Maquata. When low it is quite saline, but the salinity is destroyed whenever a flood reconnects it with the Hardy.

The area of the Salton Basin can not be accurately computed because of the character of the delta and the uncertainty in the position of the divide across it. It is probably about 8,000 square miles.

THE BASINS OF THE NEW MEXICO-TEXAS TROUGH.

The central portion of New Mexico has a structure very similar to that of the Great Basin. A somewhat warped and folded plateau has yielded to great north-south fractures, producing parallel ranges and trough valleys as in Nevada and California. The most prominent of these troughs is that occupied by the valley of the Rio Grande north of El Paso. This was once a series of separate basins or "bolsons," but the divides have been cut by the river and the entire valley is now essentially drained, though stream decay has recently created a number of local and unimportant playas. East of this trough lies another which, not possessing a vigorous through-flowing stream, has not been cut down or kept clean, and contains the several inclosed basins next to be discussed.

THE OTERO BASIN.

The middle portion of this trough is occupied by the Otero Basin, lying between the Sacramento Mountains on the east and the San Andreas Mountains on the west. The writer has published elsewhere ¹ a report of a reconnoissance of this basin from the present viewpoint, and it is necessary here only to review the essentials of the topography. East and west the basin is limited by the high walls of the trough. To the north it merges with the Gallinas highland and the Chupadera Mesa, both high and certainly pre-Lahontan. At the southern end the divide is alluvial and though apparently ancient, is probably less than 300 feet above the present deepest depression. It is quite possible that the basin has overflowed this divide and drained into the Rio Grande, but there is no direct evidence of this, and the writer does not consider it probable. In any case, a series of ancient strands about the present bottom indicates an inclosed history of some duration. The present deepest depression is a large and very gypsiferous playa, the southern end of which carries a deposit of hydrous sodium sulphate believed to be of secondary origin. There are several small local playas of no importance.

The most interesting and unusual feature of the basin is a great area of gypsum dunes, south and east of the main playa. The study of these dunes has yielded con-

¹ Circular 61, Bureau of Soils, U. S. Dept. of Agr. (1912). The reconnoissance was made in the company of Dr. Ellsworth Huntington.



FIG. 1.—BOTTOM OF DEATH VALLEY, CAL.

[Showing the salt-covered mud flat northwest of Furnace Creek Ranch.]



FIG. 2.—ROUGH CRUST OF IMPURE SALT ON THE FLOOR OF DEATH VALLEY, CAL.

clusions of some geologic interest but quite foreign to the present subject. The area of the Otero Basin is a little over 7,000 square miles.

THE ESTANCIA BASIN.¹

The Estancia Valley lies at the northern end of the trough in which is the Otero Basin and where this trough begins to merge with the plateau of northern New Mexico. It is separated from the Otero Basin by the Gallinas and Chupedera uplift and the northern and western boundaries are similarly structural. The eastern boundary is much lower and in several places is less than 250 feet above the bottom of the valley. Overflow in this direction and into the Pecos Valley is possible but not probable. The bottom of the valley is diversified by a number of shallow and irregularly-shaped depressions, believed by Meinzer to have been scooped by the wind from the beds deposited in the bottom of an ancient lake. Some of these depressions now contain salt or brackish lakes. There is the usual series of old strands about the valley.

At present the drainage of the valley is almost entirely by underflow and impossible to define. The area is about 2,050 square miles. In the northeastern corner is the small basin of White Lake, now cut off by desiccation but once a tributary. Including this the area is about 2,100 square miles. Both of the areas given are only approximate because of the comparatively low relief of the surrounding highlands and the difficulty of accurately defining the divides.

THE ENCINO BASIN.

The Encino Basin lies east of the Estancia Basin and is very similar to it. The surrounding divides, though poorly defined, are relatively high and the basin has probably been permanently inclosed. It contains the usual saline depression, believed by Meinzer to be wind-formed, and is surrounded by the usual series of old strands. Its area is about 300 square miles, great accuracy being unobtainable because of uncertainty as to the position of the divides.

THE PINOS WELLS BASIN.

The Pinos Wells Basin lies just south of the Encino Basin and is similar thereto in every way except that the eastern divide is much lower and the lake strands are lacking. The writer is of the opinion that this basin was once tributary to the Pecos Valley and has only recently been inclosed. It is not impossible that this basin is a part of a former eastward overflow channel of the Estancia Basin and, if the Estancia Basin ever did overflow, it was probably by this path. The area of the Pinos Wells Basin is about 325 square miles.

THE SALT BASIN.

Directly southeast of the Otero trough, though probably not structurally related thereto is another similar trough which contains the so-called Salt Basin, historic as the scene of the "salt riots" of 1878. The divides which surround this basin are essentially structural and ancient and though several passes are superficially alluvial, all are over 600 feet above the flat. The basin is believed to have been permanently inclosed. The floor is a nearly level plain dotted with hillocks of dune sand and with small saline lakes and playas. The present drainage is insignificant and the areas tributary to the various lakes can not be computed with any exactness. The area of the basin as a whole is about 8,600 square miles.

¹ The description of the Estancia, Encino, and Pinos Wells Basins is drawn largely from the report of Meinzer, U. S. Geol. Surv.; Water Supply Paper 275 (1911).

THE TROUGH VALLEYS OF ARIZONA AND SONORA.

Arizona south of the Gila River and the northern and western portions of Sonora form another region of great parallel ranges and valleys essentially similar to the Great Basin though somewhat more complex in the details of its structure. The trough form of the valleys is especially well developed north of the international line, being typified by the Lechuguilla and Tule "Deserts" and the Mohawk and Ajo Valleys to the west; the Quijotoa, Baboquivari, and Santa Cruz Valleys in the center, and the San Pedro, Arivaipa, and San Simon Valleys to the east. South of the line the topography is less simple and the dendritic drainage of the Altar River has cut transversely across range and valley in a way which strongly suggests the character of the Quaternary Mojave.

The great troughs of the northern section resemble those already discussed in that they are usually higher in the middle than at the ends, thus creating in each a water parting north of which drainage was once to the Gila, while southward it joined the Altar or flowed directly to the Gulf. Without exception the troughs are essentially open in one direction or the other and in the whole region there is no known basin of structural origin. Furthermore, most of the drainage lines are still open and, paradoxically, because the aridity has been too complete. The process of alluvial damming so characteristic of the troughs of the Great Basin has been impossible because the rainfall has been too meager to move the alluvium. Even the minimum of rainfall necessary for the formation of local playas has been lacking. Two streams, the San Pedro and the Altar, have their sources in higher and better watered regions, and manage to maintain a precarious existence over part of their former channels. The Sonoita, the Santa Cruz, and a few other streams have a transient and truncated wet-weather flow. With these rare and shrunken exceptions there is no drainage at all. An occasional cloudburst in the mountains is imperceptible a dozen miles below. Yet because of the very paucity of drainage the region is not one of great salt accumulation. It is too arid to be saline. The drainage has not decayed but vanished, and there is water neither for chemical rock decay and salt solution, nor for the carrying to areas of concentration of such salts as do chance to be freed. Such salt accumulations as there are are in the better watered valleys rather than in the worse.

The Quaternary history of this region is a field for speculations of peculiar interest, and not without their present importance. Climatic changes have been continent-wide and probably world-wide, and the evidences of a previous lesser aridity are unmistakable in the region to the north. Is it not probable, therefore, that the present unmitigated aridity of this southern area has replaced a time of less extreme conditions when a more moderate desiccation permitted and

caused the formation of playas and alluvial dams? This region then, was perhaps what the Great Basin is now, and salt accumulations descended from such a period are by no means impossible. But whether or not these speculations have a basis of truth, they are as yet without supporting evidence. No direct indication of such a moderately arid period has been discovered, and the country is so inhospitable that it has not invited the efforts of speculative geologists. For the present the matter must remain open and it would seem useless to search here for hypothetical salt accumulations when there are other regions, the promise of which rests less on speculation and more on fact.

THE COCHISE BASIN.

In the eastern part of the region just discussed there is one basin of more usual type. The Arivaipa-Sulphur Springs Valley, being better watered than its more westerly analogues, has had a history more nearly parallel to that of the Great Basin valleys, and the central portion of it has been cut off by alluvial dams to form the Cochise Basin. Northward the valley drains to the Gila and southward to the Rio Yaqui. The northward divide is the lower and probably the more recent, and there is little question that the basin once had free drainage in this direction. The area of the basin is approximately 1,250 square miles. It contains a playa of usual character.

THE LORDSBURG-MEMBRES REGION AND THE CHIHUAHUA BOLSONS.

In the southwestern corner of New Mexico are two trough valleys not essentially dissimilar to the Arizona trough valleys which border them on the west, but of much less regular structure. The western of these troughs contains the present Lordsburg and San Luis Valleys and belongs in many ways with the Cochise Basin and the San Simon Valley, in the group last discussed. Once it drained northward into the Gila and it is now cut off therefrom only by a low alluvial divide. Internally the valley shows a topography essentially similar to that of the valleys of the Great Basin. The structural trough has two branches, each of which once contained a considerable stream, the two uniting somewhat south of their mutual discharge into the Gila. Stream decay and alluvial dams have cut these tributaries into chains of shallow basins and local playas, notable among which are the Llano de los Playas, or Playas Valley, lying southeast of the Pyramid Mountains, and the Lordsburg Dry Lake near the railroad junction of that name. All of these subsidiary basins are recent and unimportant and their individual areas have not been computed. The total area of inclosed drainage in the trough is about 2,900 square miles.

East of this trough is another irregular trough valley now containing the valley of the Membres River and the Florida Plains. In this trough the inclination is reversed and the former drainage was southward across the international line. Indeed, there is now scarcely any barrier to southward drainage and a very moderate

increase of rainfall would suffice to reestablish the outflow. Stream decay has produced a few local playas, but none of any importance.

Southward of the line the ancient drainage line reaches the Laguna Guzman, which is the sink of the northernmost of the Chihuahua bolsons. The area of the Membres Valley and its tributaries within the United States is over 5,000 square miles. In Mexico an area of 6,800 square miles is or has been tributary to the Laguna Guzman, making a total of about 11,800 square miles for the area of this bolson.

These bolsons are wide, shallow basins once tributary to the Rio Grande and now cut off therefrom only by low dams of alluvium and dune sand. They are products of the decay of the drainage system which once served the broad featureless plains between the Rio Grande and the Sierra Madre. All are very recent and unimportant. The larger ones contain intermittent or permanent lakes fed by the perennial streams which head in the well-watered highlands of the Sierra Madre. The region of the bolsons extends from the western boundary of Chihuahua southeastward to the edge of the drainage system of the Rio Salado, about half way across the State of Coahuila, but this region is divided into two parts by the still vigorous drainage system of the Rio Conchos. The north-western portion is the smaller and contains the bolsons of the Laguna¹ Guzman (already discussed), the Laguna de Santa Maria, the Rio Carmen, and the Laguna de Patos, as well as many smaller playas and transient ponds. The more important bolsons of the southern division are those of Laguna Palomas, Laguna de Coyote, Laguna Parras, Laguna Viesca, Laguna de Jaco, and Laguna de Agua Verde. Areas have not been computed in detail. The total area covered by all the bolsons, including the Guzman, is probably not less than 125,000 square miles.

THE ROCKY MOUNTAIN BASINS.

The crests of broad mountain ranges are frequently regions of poorly determined drainage and wherever the crest of the Rockies is flat and imperfectly defined, advancing desiccation has left small valleys and local depressions partially or entirely without outward drainage. All such basins are more or less recent and nearly all are small. Only two require specific notice.

THE SAN LUIS BASIN.

The San Luis Valley or San Luis Park lies in south-central Colorado at the head of the great trough of the Rio Grande. It is separated from the valley of this river by a broad and featureless alluvial plain, crossed by an inconspicuous divide. The present drainage of the valley is not sufficient to overflow this divide, and accumulates

¹ Laguna is the Spanish word for lake; rio is that for river.

in a group of small and variable lakes. The inclosed condition of the valley is undoubtedly very recent and due only to stream decay. The area of the present basin is about 2,800 square miles.

THE RED DESERT BASIN.

The Red Desert Basin, or group of basins, lies in south-central Wyoming, on the very crest of the Rocky Mountains, occupying a broad plain bordered on three sides by mountain ranges but essentially open toward the south. At a time by no means remote this southern divide was nonexistent and the basin drained, probably freely but at least by overflow, into the Little Snake River and thence to the Colorado. The present barrier is a series of low divides which are superficially alluvial and probably entirely so. The basin is by no means a unit but is cut by alluvial or structural divides into a complex series of smaller basins each with its playa and its greater or lesser drainage. The past and present relations of these basins are not known in detail, but it is improbable that their discharge ever concentrated in a single basin or a single channel of escape. The region is more a decayed drainage system than a single basin.

None of these basins is ancient, and none would have any importance were it not for the fact that part of the western slope of the area is formed by the Leucite Hills, a zone of volcanic activity in which are large masses of leucitic rocks containing considerable proportions of potash.¹ How fully the drainage of these hills has been localized and retained can not be determined from present data. The writer inclines to the opinion that both retention and concentration have been comparatively slight, but the evidence is far from conclusive, and the region can not be disregarded. It should be noted that the presence of extensive deposits of sodium salts in the basins of the Red Desert and in other small basins both west and east of it is no proof of long-continued concentration. The shales and sandstones which make up the greater portion of the areas tributary to these basins contain large quantities of occluded sodium salts, which rapidly find their way into the drainage and to the places where it concentrates.

West of the Red Desert and on the westward slope of the Leucite Hills are several small and local basins now without overflow and which share the topography and geochemical characteristics of the western part of the Red Desert proper.

The total area of the Red Desert Basin is approximately 3,600 square miles, but it is apparent from the above discussion that importance lies not in the total area, but in the areas and topographies of the various subsidiary basins and in what proportion of leucitic country chanced to be tributary to each. These facts can not be determined from the information now available.

THE GREAT VALLEY OF CALIFORNIA.

Through the heart of California, between the Sierra Nevada and the Coast Range, runs a great filled trough which differs from the "basin troughs" east of the Sierra only in its greater size and in the fact that its western wall is breached by the Golden Gate, giving free egress to the sea. Southward through the north end of this valley flows the Sacramento River, and northward from the south end comes the San Joaquin, both rivers uniting to form the Straits of Suisan and entering the sea through San Francisco Bay and the Golden Gate. In essence both the Sacramento and San Joaquin Valleys are regions of free seaward drainage, but rainfall is low, and is insufficient to keep the valleys entirely clear. Local playas and "alkali" spots

¹ See Schultz and Cross, U. S. Geol. Sur., Bull. 512 (1912).

are not uncommon, and, especially in the San Joaquin, shallow local depressions have become small inclosed basins or lakes like Kern and Tulare, which overflow only at times. Here, as in the Great Basin, evidences of stream decay are everywhere. None of these local basins are structural, none have walls high enough to be even directly perceptible, and none have any significant antiquity. The saline accumulation gets no further than the formation of "alkali" soil, and has no significance to the present inquiry.

THE FILLED LAKES OF THE CALIFORNIA RANGES.

In the mountains of these ranges, as of most others, are many small depressions which are or have been filled by lakes. In the course of time these lakes have been slowly filled by alluvium, and at the same time their outlets have been slowly lowered by stream corrasion, until at last the rising alluvium met the falling water surface and the lakes have become flat-filled valleys with a more or less vigorous original or through-flowing drainage. Examples of this process, locally modified, have already been mentioned—the Antelope Valley in Oregon (p. 25), the Smith Valley in Nevada (p. 18), and the Tehachapi Valley in California (p. 42). Literally hundreds of others in all stages of development may be found in the Sierra, the Coast Range, the Cascades, and elsewhere. Plate I, fig. 1.

Where the drainage is sufficiently vigorous, either because through-flowing or for some other reason, these filled lakes do not interest us. In many cases, however, an original drainage, never very vigorous, has not been able to maintain itself and has been imprisoned within the valley. Probably the most extreme instance of this is the basin of the Carriso Plains in the southeastern corner of San Luis Obispo County, Cal.¹ Nearly 500 square miles of this valley, once tributary to the San Juan Creek, have been cut off by alluvial deposition and stream decay probably complicated by local movement, and have developed an internal drainage concentrating in Soda Lake, which is now a playa saturated with a strong salt solution in which sodium sulphate predominates. Of course this condition is quite recent, and, from the present viewpoint, quite unimportant.

THE BASINS AND PONDS OF THE COLORADO PLATEAU.

The northern third of Arizona, the northwestern quarter of New Mexico, and adjoining portions of Utah and Colorado make up the Great Colorado Plateau. Subjected to some movement and considerably dissected by the Colorado and its tributaries, this plateau nevertheless retains wide areas in which relief is small and slope imperceptible, and over which drainage is at best sluggish and uncertain. These areas have suffered greatly from the prevalent desicca-

¹ Arnold and Johnson, U. S. Geol. Sur., Bul. 380, 369 (1909).

tion. Valleys dammed by alluvium, local depressions dried below their outlets, ponds like those of the Great Plains and coulées, as well developed as those of Washington, all abound. Many of these inclosed areas are of considerable salinity, but all are recent and most are tiny, and it does not seem necessary to discuss them in detail. In area they vary from ponds or playas that drain a few acres to the large but shallow basin of the plains of San Augustine in western New Mexico, compassing perhaps 1,500 square miles. This latter basin and the smaller ones in its vicinity probably once drained into the Rio Grande instead of the Colorado, but otherwise they do not differ from their western analogues. In the absence of full and detailed knowledge of the entire plateau region it is impossible to deny categorically the existence of basins, the size or antiquity of which would give them present interest. However, it seems very probable that, with one exception, no such exist. This exception will now be described.

THE HUALPAI BASIN.

In its southwestern portion the Colorado plateau has been more modified than elsewhere, both by movement and erosion, and here lies the Hualpai or Red Lake Valley, occupying a depression in the making of which both movement and erosion have had a hand. There is little doubt that this valley once drained northward to the Colorado, but this drainage may have been a long time ago. The present divide, though alluvial, is high and may be pre-Lahontan. The writer, while inclining to the opinion that it is, does not care to advance any conclusion. The area of the basin is approximately 1,450 square miles and its deepest depression contains a playa which is not known to be especially saline.

THE PONDS AND COULÉES¹ OF EASTERN WASHINGTON.

The central and eastern part of Washington is largely a great lava plateau, somewhat warped and cracked by the movement which was more pronounced farther south and west, but preserving much of its original character. Being of little relief and in general of poorly developed drainage, this plateau has suffered severely by desiccation and is now dotted with literally hundreds of small inclosed basins, due primarily to inequalities in the lava surface and resembling in every way the small pans of the Christmas Lake, Abert and Alkali Valleys, as discussed on pages 22 to 26. Some of these depressions now carry permanent or intermittent lakes, most are slightly or moderately saline, but all are recent and owe their inclosed condition to the decay of the drainage system to which they once belonged. So far as known none drain an area of over a few square miles and none are important.

Another and less usual type of inclosed basin is represented by the "coulées," or long, narrow valleys with steep walls and flat floors, the floors being dotted with lakes. Essentially these are old stream channels, the history of which, stripped of all details, is as follows. When the lava plain was uplifted and warped, numerous cracks formed

¹ The word "coulée" is here used as locally understood.

across it, usually without much vertical displacement on either side. As the rainfall was then (or later) much greater than at present, these cracks determined stream channels and became eroded to considerable depths and with a steep-walled, canyon topography. Later ice-dammed lakes occupied these valleys and supplied the alluvium which forms the present flat bottoms. With the disappearance of these lakes the valleys again became stream channels but apparently not for long. Desiccation intervened and the once through-flowing streams were split into a series of pools or playas. This is the present condition of the coulées. Some of the lakes overflow and are fresh, others do so seldom if ever and are brackish or saline. In Grand Coulée is one—Soap Lake—which is a nearly saturated brine and contains an extraordinarily large proportion of carbonate of soda. But interesting as is this history of the coulées, it indicates clearly the recency of the lakes which occupy them, and therefore their unimportance to the present inquiry. None of their areas have been computed.

THE PONDS OF THE GREAT PLAINS.

The western half of the Mississippi Valley is a great apron sloping imperceptibly upward to the mass of the Rockies. Over this in Quaternary time stretched a complexly dendritic drainage system, its finger tips reaching to the crest of the mountains and to every ridge and hill between, so that each township had its river and every acre its rill. But advancing aridity has respected this greatest river system no more than the lesser ones to the west. Its streams have been clogged and truncated and its remotest and slenderest tendrils withdrawn, until to-day there is a large area at the foot of the Rockies which has nearly no drainage at all. In all this region alluvial dams and sand dunes (the latter much more than the former) have advanced upon the defenseless drainage, damming the little streamlets in a dozen places, cutting off here and there a tributary of more considerable size, creating tiny and tinier basins now numbered by the thousands. These dot the whole plains region of Nebraska and Wyoming, the northwestern corner of Kansas, the eastern fourth of Colorado, the dune areas of southwestern Kansas, and the great plains of the Pecos Valley and the Llano Estacado, but they are perhaps best exemplified in the Sand Hills of Nebraska.¹ Here alluvium and dunes and have conspired against the drainage and with entire success. The region is a wilderness of rolling hills, originally dunes but now fixed by vegetation with the intermediate valleys dotted with lakes varying in area from a few acres to 2 or 3 square miles. There is usually an annual fluctuation in level of 1 or 2 feet from a maxi-

¹ For much of the information here given I am indebted to Prof. Raymond J. Pool, of the University of Nebraska.

mum in early spring to a minimum in late autumn. Most of the lakes do not overflow and many of them are brackish. All are unquestionably recent and due to sand accumulations which the drainage has never since been vigorous enough to clear away.

Farther south, where the rainfall is less, are playas instead of lakes, but otherwise conditions are the same. Everywhere the outposts of the drainage system have retreated and their channels have been barred. The bars are sometimes alluvial, sometimes eolian, more often both. The result is the same.

Of course none of the basins thus created could ever become the place of accumulation of any large quantity of salt. It is an essential of the process outlined that large basins can not be created, since their concentrated drainage would be sufficient to sweep away the dam. Where a stream of any size is permanently dammed by sand or alluvium it must be dammed in many places and split into many basins in order that evaporation may be sufficient to balance or overbalance the inflow. In places ponds may become quite saline, but the total amount of salt accumulated is always small.

It is of special interest in the present connection to note that some small saline ponds in western Nebraska have been found to contain very large proportions of potassium carbonate undoubtedly derived from the concentration of the run-off of burnt-over prairies. Were there a place where concentration of this kind had occurred for a long time or from a considerable area, a workable deposit of potassium salts might have accumulated. No such place has been discovered and it is probable that none exists.

LOCAL BASINS OF UNUSUAL ORIGIN.

For the sake of completeness it is necessary to note briefly a few areas of inclosed drainage which have originated from local and unusual causes. These are of two types—volcanic and eolian. The craters of extinct volcanos frequently contain inclosed lakes and there is at least one example of this in the United States—Crater Lake, Oreg. The Ragtown Soda Lakes, near Fallon, Nev., noted on page 15, are probably of similar origin, though the vulcanism was far less vigorous. Apparently the Zuni Salt Lake on the plateau of north-western New Mexico is of the same type.¹ In both the latter cases the salinity of the inclosed lake is due to the concentration of water received from seepage or springs.

Basins due to "deflation," or eolian erosion, have only one prominent example in the United States. West of Laramie, Wyo., are three or four isolated depressions, one of which, Bates Hole, is of considerable size and depth. These have been studied by Blackwelder² who

¹ Darton, U. S. Geol. Survey, Bul. 260, 565 (1905).

² Jour. Geol., 17, 443 (1909).

regards them as due to wind erosion. The similar though smaller wind-eroded hollows of the Estancia Basin, New Mexico, were noted on page 49, and the writer has seen analogous depressions in the Alkali and Warner Basins, Oreg. Both volcanic and eolian basins are likely always to be too small to have importance for the present study. This is certainly true of all known American examples.

THE POSSIBILITIES OF POTASH.

In the preceding pages there are named specifically nearly 200 inclosed basins. Some of these are so obviously unimportant as to require no further mention. One hundred and twenty-six, which are somewhat more important, are given in Table I, with the area and a brief description of each, the arrangement being the same as that followed in the text. It is certain that any basins of possible value for potash will be included in this list, and it is just as certain that many that are included will have no possible value. Many of the latter are easily eliminated. First, it is obvious that no accumulation is to be expected in a basin which has recently overflowed either into the sea or into another basin. Applying this to the list of Table I, it is possible to eliminate from further consideration 62 basins, of which 16 were once tributary to Lahontan, 9 to Bonneville, 11 to the Amargosa and the Mojave, 7 to miscellaneous inclosed basins, and 19 more or less directly to the sea. These totals include 10 basins the previous drainage of which is not absolutely certain, though extremely probable. These are the Clover Basin, the Goshute-Steptoe Valley, the Murray Valley, the Ralston Valley, Stonewall Flat, Summer Lake, Long Valley (northwestern Nevada), Duck Flat, the Big Smoky Valley, and the Smiths Creek Valley. The nature of the doubt in each case can be ascertained by reference to the preceding chapter.

A second general elimination can be made on the ground of small area. It is difficult to set exactly the limiting area which a basin must have in order to be promising, but it seems probable that basins which cover less than 500 square miles may safely be disregarded. Their potash deposits, if existent, would doubtless be small, and detailed prospecting would scarcely be warranted at least until larger basins have been explored. Applying this criterion to the remaining basins of Table I, we eliminate 10 more, Alkali Lake, Garfield, Teels, Huntoon, Goldfield, Sheep Range, Willard, Granite Mountains, Owl, and Encino. It is possible also to eliminate 12 others which were very probably drained, but which, in any event, are smaller than the upper limit which we have set. These are Warm Springs, Allan Springs, Mesquite (part of the Pahrump), Acme, Luning, Mina, Monte Cristo, Kawich, Yucca, Aurora, Deep Springs, and Pinos Wells. The conclusion that these small basins lack practical value does not

necessarily mean that they lack scientific interest. For instance, the small saline ponds of Alkali Lake are known to contain about 4 per cent of potash (K_2O) in their total dissolved solids, and the Teels Marsh carries a number of the minerals which are associated with potash brines at Searles. It is quite possible that some of these smaller basins may prove to contain potash accumulations of relatively high grade, but the amount of the material is likely to be too small to warrant commercial exploitation.

It is possible to eliminate two additional basins on special grounds. First, Bonneville, in spite of its great size, can be safely dropped from the list of possibilities. This is true on two grounds—previous overflow and the areal geology of the basin. The overflow in itself might not be sufficient, for there has been a considerable period since the overflow ceased and time has probably been available for extensive potash accumulation. But the Bonneville Basin is set almost entirely in sedimentary rocks, which can not reasonably be expected to yield any important quantity of potash to the drainage. Furthermore, nearly all of the saline material accumulated within the basin is probably now in the Great Salt Lake, and the salts contained in this lake carry less than 2 per cent of potash (K_2O).

The last basin to be eliminated is the Otero, in central New Mexico. This was possibly once subject to overflow and is set almost entirely in nonpotash rocks, but its elimination is not based upon these facts so much as upon a detailed examination made of the basin specifically from the present point of view, and which resulted in a strongly negative conclusion.¹

The basins which remain may be divided into three divisions: (1) Those in which the known topographic and geologic conditions are fully favorable, (2) those in which some conditions are favorable and some adverse, and (3) those concerning which there is sufficient uncertainty to render classification doubtful and decision as to promise impossible. The basins of these three divisions are given in Tables II and III and IV, respectively. Of those in Table III the topographic features are favorable in all cases but one—Owens. In this case the previous overflow into Searles introduces an unfavorable factor which has, however, been partially overcome by the length of time elapsed since this overflow ceased. At the present time the salts of Owens Lake contain approximately 2.25 per cent of potash (K_2O). With the other basins of Table III the unfavorable factor is in all cases a lack of potash-bearing rocks in the drainage basin, the Che-waucan Basin being set almost entirely in basalts and the others in Paleozoic sediments.

Of the uncertain basins of Table IV, the Salton is doubtful, because of the difficulty of interpreting the influence of the Colorado River

¹ Free, Circ. No. 61, Bureau of Soils, U. S. Dept. of Agr. (1912).

upon it; Rhodes is unpromising, because of its small drainage area and the probability that this area was really considerably smaller than that given, and the uncertainty concerning the Red Desert arises from lack of knowledge of its internal topography. In all other cases the doubt is due to uncertainty as to area or previous overflow, usually the latter. Details of all cases are contained in previous pages.

The basins of Table II are, so far as known, all favorable to potash accumulation and, other things equal, they should be promising in proportion to their area. These "other things" are believed to be really equal so far as accumulation is concerned. Questions of segregation and accessibility introduce many other factors which are beyond the province of this report and will not be discussed.

It is believed, however, that the introduction of these additional factors into the discussion would find its main effect in altering the order in which the basins stand in Table II rather than in adding basins thereto or subtracting them therefrom. The basins of greatest promise from all points of view are probably contained in Table II, with the possible addition of such of those of Table IV as further investigation may show to be favorable.

TABLE I.—*Areas of the undrained basins.*

Basin.	Description.	Area.	Basin.	Description.	Area.
		<i>Sq. m.</i>			<i>Sq. m.</i>
Lahontan.....		45,730	Warner.....	Landlocked.....	2,000
Black Rock.....	Part of Lahontan.....	10,500	Harney.....	Tributary to Colum- bia River.....	
Kumiva.....	do.....	445	Catlow.....	Probably tributary to Harney.....	2,000
Granite Spring.....	do.....	890	Guano.....	Probably tributary to Catlow.....	1,000
Jungo.....	do.....	340	Surprise.....	Landlocked (max. area).....	2,350
Hot Springs.....	do.....	270	Long Valley.....	Probably tributary to Surprise.....	775
Honey Lake.....	do.....	2,660	Alvord.....	Probably landlocked..	3,200
Truckee.....	do.....	2,975	White Horse.....	Tributary to Alvord..	300
Lemmon Valley.....	do.....	90	Thousand Creek.....	do.....	1,300
Warm Springs.....	do.....	20	Goose Lake.....	Tributary to Pitt River.....	
Humboldt-Carson.....	do.....	27,575	Madeline.....	Probably landlocked..	900
Fernley.....	do.....	215	Klamath Lakes.....	Tributary to Klamath River.....	
Allen Springs.....	do.....	235	Dixie Valley.....	Landlocked.....	2,290
Sand Springs.....	do.....	200	Fairview.....	Part of Dixie.....	290
Buena Vista.....	Part of Humboldt drainage.....	4,000	Gabbs Valley.....	Landlocked.....	1,280
Buffalo Springs.....	do.....	500	Acme.....	Probably tributary to Walker.....	130
Gibson.....	do.....	1,150	Luning.....	Probably tributary to Rhodes.....	175
Clover (Snow Water) ter).....	do.....	1,075	Mina.....	do.....	65
Walker.....	Part of Lahontan.....	3,850	Rhodes (max. area).....	Probably landlocked..	670
Bonneville.....	Once tributary to Columbia River.....	57,960	Garfield.....	do.....	90
Step toe.....	Part of Bonneville.....	6,590	Teels.....	Landlocked.....	320
Ruby.....	do.....	1,200	Huntoon.....	do.....	115
Butte Valley.....	do.....	740	Monte Cristo.....	Doubtful.....	300
Murray.....	do.....	720	Columbus.....	Landlocked.....	1,350
White Valley.....	do.....	920	Clayton.....	do.....	550
Rush Valley.....	do.....	700	Big Smoky.....	do.....	3,325
Cedar Valley.....	do.....	300	Kingston.....	Tributary to Big Smoky.....	1,190
Sevier.....	do.....	16,375	Edwards Creek.....	Landlocked.....	990
Round Valley.....	do.....	170	Smiths Creek.....	Probably tributary to Edwards Creek.....	500
Christmas Lake.....	Probably landlocked..	2,750			
Silver Lake.....	Part of Christmas Lake Basin.....	750			
Chewaucan (Abert Lake).....	Landlocked.....	1,500			
Summer Lake.....	Part of Chewaucan Basin.....	560			
Alkali Lake.....	Landlocked.....	400			

TABLE I.—*Areas of the undrained basins—Continued.*

Basin.	Description.	Area.	Basin.	Description.	Area.
		<i>Sq. m.</i>			<i>Sq. m.</i>
Goldfield.....	Probably landlocked..	330	Soda Lake.....	Part of Mojave drainage.	
Diamond.....	do.....	2,800	Rodriguez Lake.....	do.....	
Railroad Valley.....	Landlocked(max. area)	6,340	Harper Lake.....	do.....	
Kawich.....	Probably tributary to Railroad.	370	Coyote Lake.....	do.....	
Penoyer.....	do.....	1,000	Cronese Lake.....	do.....	
Gold Flat.....	Probably landlocked..	640	Langford Lake.....	do.....	
Emigrant.....	Probably landlocked (max. area).	1,000	Ivanpah.....	Landlocked.....	900
Yucca.....	Probably tributary to Frenchman Flat.	300	Mesquite Lake.....	Tributary to Colorado River.	
Frenchman Flat.....	Probably landlocked..	740	Dale Lake.....	do.....	
Indian Spring.....	Tributary to Colorado River.	650	Palen Lake.....	do.....	
Pintwater.....	do.....	730	Bristol Lake.....	Probably tributary to Colorado River.	2,520
Lee Canyon.....	do.....	300	Cadiz Lake.....	Tributary either to Danby Lake or to the Colorado River.	
Sheep Range.....	Doubtful.....	300	Danby Lake.....	Probably tributary to Colorado River (max. area).	4,150
Spring Valley.....	do.....	1,550	Salton.....	Complicated by marine invasion.	8,000
Gannett.....	Tributary to Colorado River.	150	Laguna Maquata.....	Connected with Rio Hardy (Colorado River).	
Opal Mountain.....	Probably landlocked..	580	Otero.....	Probably landlocked	7,000
Mono.....	Landlocked.....	770	Estancia.....	do.....	2,100
Aurora.....	Part of Mono.....	95	Encino.....	do.....	300
Owens.....	Once tributary to Searles.	2,825	Pinos Wells.....	Probably tributary to Pecos River.	325
Searles.....	Landlocked(max. area)	4,850	Salt.....	Landlocked.....	8,600
Panamint.....	Landlocked (area does not include Searles or Owens).	1,950	Cochise.....	Tributary to Gila River.	1,250
Saline Valley.....	Landlocked.....	845	Lordsburg Dry Lake.....	do.....	
Eureka.....	do.....	775	Playas Valley.....	do.....	
Deep Springs Valley.....	Probably tributary to Eureka.	185	Laguna Guzman (Membres Valley).	Tributary to Rio Grande.	11,800
Kane.....	Probably landlocked..	900	San Luis Valley.....	do.....	2,800
Willard.....	do.....	250	Red Desert.....	Probably tributary to Colorado River.	3,600
Granite Mountain.....	do.....	150	Carriso Plains.....	Tributary to Pacific Slope drainage.	500
Owl.....	do.....	60	Plains of San Augustine.	Tributary to Rio Grande.	1,500
Death Valley.....	Landlocked (inc. Mojave and Amargosa).	23,560	Hualpai.....	Probably landlocked	1,450
Ralston Valley.....	Part of Amargosa drainage.	1,750			
Stonewall Flat.....	do.....	345			
Sarcobatus Flat.....	do.....	755			
Pahrump Valley.....	Tributary to Amargosa (max. area).	1,400			
Mesquite Valley.....	Probably tributary to the Amargosa.	350			

TABLE II.—*Basins in which all known conditions are favorable to the accumulation of potash salts, given in order of area.*

Basin.	Area.	Basin.	Area.	Basin.	Area.
	<i>Sq. m.</i>		<i>Sq. m.</i>		<i>Sq. m.</i>
Lahontan.....	45,730	Warner.....	2,000	Saline.....	845
Death Valley.....	23,560	Panamint.....	1,950	Eureka.....	775
Railroad Valley.....	6,340	Hualpai.....	1,450	Mono.....	770
Searles.....	4,850	Columbus.....	1,350	Frenchman Flat.....	740
Alvord.....	3,200	Gabbs.....	1,280	Gold Flat.....	640
Diamond.....	2,800	Edwards Creek.....	990	Opal Mountain.....	580
Surprise.....	2,350	Kane.....	900	Clayton.....	550
Dixie.....	2,290	Ivanpah.....	900		

TABLE III.—*Basins in which some of the known conditions are unfavorable to the accumulation of potassium salts but which cannot be definitely rejected, given in order of area.*

Basin.	Area.	Basin.	Area.	Basin.	Area.
	<i>Sq. m.</i>		<i>Sq. m.</i>		<i>Sq. m.</i>
Salt Basin.....	8,600	Estancia.....	2,100	Chewaucan (Abert Lake)	1,500
Owens.....	2,825	Spring Valley.....	1,550		

TABLE IV.—*Basins the classification and promise of which is doubtful, given in order of area.*

Basin.	Area.	Basin.	Area.	Basin.	Area.
	<i>Sq. m.</i>		<i>Sq. m.</i>		<i>Sq. m.</i>
Salton.....	8,000	Bristol Lake.....	2,520	Emigrant (Timpahute).	1,000
Danby Lake.....	4,150	Catlow.....	2,000	Madeline.....	900
Red Desert.....	3,600	Penoyer.....	1,000	Rhodes.....	670
Christmas Lake.....	2,750	Guano Lake.....	1,000		

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BALSAM FIR.

By RAPHAEL ZON,
Chief of Forest Investigations.

INTRODUCTION.

The enormous expansion of the pulp industry in this country during the last two decades, with its present annual demand for not less than three and a quarter million cords of coniferous wood, has stimulated the use of balsam fir, which but a few years ago was considered of little value. With the increase in the price of spruce for pulpwood, balsam fir has begun to take its place for rough lumber, laths, shingles, and box shooks. The cutting of balsam fir to any extent for pulp or lumber began only about 20 years ago, as the more valuable species of the northern forests became scarce and as its suitability for many purposes for which only white pine or spruce were originally used became recognized.

Balsam fir, though in general inferior to white pine and red spruce, is now a tree of considerable economic importance in the northeastern forests. It constitutes numerically about 20 per cent of the coniferous forests in northern New York and Maine, and is abundant in many parts of New Hampshire, Vermont, and in the swamps of northern Michigan, northern Wisconsin, and Minnesota. Through prolific seeding and rapid growth it readily reforests cut-over areas and attains sizes suitable for pulpwood in a short time.

The uses for which balsam fir is suited and the appearance of barked wood, especially after it has remained for any length of time in water, are so much like those of spruce that it is commonly sold in mixture with and under the name of spruce, because of a lingering prejudice against balsam fir among pulp manufacturers and lumbermen. This prejudice, formed at the time of still abundant supplies of spruce and

NOTE.—This bulletin deals with all aspects of balsam fir, its distribution, the forest types in which it occurs, the present stand and cut, its economic importance, especially in relation to the paper-pulp industry, methods and cost of lumbering, life history of the tree, characteristics of the wood, rate of growth and yield, and proper methods of management. Balsam fir is found in commercial quantities in the northeastern border States from Maine to Minnesota.

white pine, is based partly on the actual inferiority of balsam fir to those species and partly to insufficient familiarity with the wood.

To determine impartially the economic value of balsam fir, its distribution, present stand and cut in the various States where it occurs, as well as its qualities and possibilities as a forest tree, was the purpose of two summers' study in the Adirondacks, in Maine, and throughout the whole of the tree's commercial range. It was believed that by pointing out the possibility of using balsam fir in places where originally only spruce had been used, and by learning its peculiarities as a forest tree, the heavy drain upon our waning supplies of spruce might be slightly decreased, and that suggestions for the proper management of our spruce forests, in which balsam fir holds an important place, could be formulated.

DISTRIBUTION OF BALSAM FIR.

Balsam fir (*Abies balsamea* Mill.) is a tree chiefly of the Northeast, although it occurs here and there in the mountain ridges of southern Virginia and extends westward in Canada as far as Mackenzie River. (See map, fig. 1.)

Moisture and temperature are the two main factors influencing its distribution. It requires a cold climate and a constant supply of moisture at its roots. A mean annual temperature not exceeding 40° F., with an average summer temperature of not more than 70° F., and a mean annual precipitation of not less than 25 inches evenly distributed throughout the year, are the necessary conditions for its growth. It extends farther north than red spruce, but is left slightly behind by black and white spruce, tamarack, aspen, and paper birch.

Though in Canada balsam fir extends almost to the Rocky Mountains, in which it is doubtless supplanted by Alpine fir (*Abies lasiocarpa*),¹ it does not occur in continuous large forests west of the one hundredth meridian, and in the United States its western limit is found in Minnesota. One of the principal reasons for this is the increasing dryness of the air which the tree encounters in its westerly distribution. The mean annual rainfall gradually decreases from the east toward the west. In Maine, where balsam fir reaches its best development, the rainfall amounts to 43 inches; in Minnesota, where balsam is of poor development, it is less than 26 inches. Farther west, in North Dakota, the annual rainfall drops to about 18 inches, and no balsam fir is found. While the increasing dryness of the air influences the western distribution of balsam fir, the increasing temperature controls its southern distribution, limiting it to higher and higher elevations the farther south it extends, until it gives way to Frazer fir (*Abies frazeri* (Pursh.) Lindl.) on the highest mountains of West Virginia, North Carolina, and Tennessee.

¹ John Macoun. Geological and Natural History Survey of Canada: Catalogue of Canadian Plants. Part III—Apetalæ, p. 473.

The northern limit of balsam fir's botanical range extends from Labrador and Newfoundland southwestward, crossing James Bay at latitude 54° north and, keeping slightly south of Hudson Bay, passing between Fort Severn and Front Lake to Hayes River. From



FIG. 1.—Distribution of balsam fir.

this point it turns abruptly again southward and crosses Nelson River at the outlet of Sipiweesk Lake; thence it takes a northwesterly direction to the Great Bear Lake region until it reaches and probably crosses Mackenzie River. The most northern point at which balsam fir has been observed is 62° .

Southward balsam fir is found almost all over Canada, particularly in its maritime provinces—Quebec and Ontario—in northern New England, and in the northern parts of New York, Michigan, Wisconsin, Minnesota, and northeastern Iowa. Along the Appalachian Mountains it extends through western Massachusetts, over the Catskills of New York, and through western Pennsylvania to the mountains of southwestern Virginia.

The heaviest commercial stands of balsam fir are found in Canada, in Quebec and Ontario. On the Cape Breton Islands, according to Dr. Fernow,¹ balsam fir forms a solid forest, with not over 15 per cent of spruce and a small admixture of paper birch, covering a plateau of 1,000 square miles. It is estimated to compose more than 50 per cent of the forest, 150,000 square miles in extent, on the southern slope of the Laurentian shield, south of the height of land. In the United States balsam fir is found in commercial quantities in most of Maine, the northern parts of New Hampshire, Vermont, New York, and to some extent also in the swamps of northern Wisconsin, northern Michigan, and Minnesota, or, in all, over an area of approximately 35,000 square miles.

FOREST TYPES.

The same factors that control the geographical distribution of balsam fir influence to a great extent also its local occurrence. Maine, with an average summer temperature of only 62.5° F., an average winter temperature of 20° F., and a mean annual rainfall of 43 inches, presents most favorable conditions for the tree's growth, and, indeed, here balsam fir is in general more thrifty than in any other State in which it occurs. This is shown in every way—in the greater height, larger diameter, greater clear length, more cylindrical shape of the trunk, and the smoother appearance of the bark, indicating a more rapid growth.

The forest types in which balsam fir occurs in Maine, as well as throughout northern New York, New Hampshire, and Vermont, may be classified as swamp, flat, hardwood slope, and mountain top.

SWAMP.

The swamp type occupies low, poorly drained, swampy land which never becomes entirely dry, and on which sphagnum and other mosses form the predominating ground cover. In such swamps balsam fir grows in dense stands and remains exceedingly slender, but is remarkably free from injury by fungus, especially from ground rot and from wind and frost cracks. It often grows nearly pure, though commonly it is mixed with black and red spruce, white cedar, and tamarack.

On account of its small size and slow growth, the balsam fir of the swamps is of little commercial value. This slow growth may be attrib-

¹ Forest Problems and Forest Resources of Canada, by Dr. B. E. Fernow, University of Toronto. Proceedings of the Society of American Foresters, Vol. VII, No. 2, 1912.

uted to two causes, excess of moisture and a short growing season. The dense evergreen foliage of the coniferous trees, as well as the ground cover of moss, shields the ice which forms in the ground during winter against the rays of the sun in the spring. Thawing, and therefore the root activity of the trees, begins later in the swamps, often five weeks, than on the slopes or dry flats.

The characteristic ground cover of balsam swamps is made up of mosses, which form about 70 per cent of the herbaceous vegetation. The character of the vegetation and the relative proportion of the different species which compose the ground cover of the swamps is as follows:

Mosses (70 per cent):

Common—

- Sphagnum.
- Fern moss (*Hylocomium proliferum*).
- Shaggy moss (*Hylocomium triquetrum*).
- Scale moss.

Occasional—

- Crane moss (*Dicranum fuloum*).

Fern and fern allies (10 per cent):

Common—

- Spinulose shield fern (*Dryopteris spinulosa*).
- Cinnamon fern (*Osmunda cinnamomea*).
- Lady fern (*Asplenium felixfemina*).
- Long beech fern (*Phegopteris phegopteris*).
- Oak fern (*Phegopteris dryopteris*).
- Marsh shield fern (*Dryopteris phegopteris*).
- Crested shield fern (*Dryopteris cristata*).
- Sensitive fern (*Onoclea sensibilis*).

Rare—

- Fernata grape fern (*Botrychium obliquum*).
- Horsetail (*Equisetum sylvaticum*).

Flowering plants (20 per cent):

Common—

- Wood sorrel (*Oxalis acetosella*).
- Gold thread (*Coptis trifolia*).
- Bunchberry (*Cornus canadensis*).
- Dalibarda (*Dalibarda repens*).

Flowering plants (20 per cent)—Continued.

Common—Continued.

- Sweet white violet (*Viola blanda palustriformis*).
- Creeping snowberry (*Chiogenes hispida*).
- Clintonia (*Clintonia borealis*).
- Wild sarsaparilla (*Arata nudicaulis*).
- Twin flower (*Linnaea borealis*).

Occasional—

- Chickweed wintergreen (*Trientalis americana*).
- Painted trillium (*Trillium undulatum*).
- Two-leaved Solomon's seal (*Unifolium canadense*).

Rare—

- Creeping wintergreen (*Gaultheria procumbens*).
- Indian pipe (*Monotropa uniflora*).

Underbrush:

Common—

- Green alder (*Alnus alnobetula*).
- Mountain ash (*Pyrus americana*).
- Withe rod (*Viburnum cassinoides*).

Occasional—

- Mountain holly (*Ilicoides mucronata*).
- Fetid currant (*Ribes prostratum*).
- Swamp honeysuckle (*Lonicera oblongifolia*).
- Pale laurel (*Kalmia glauca*).
- Mountain maple (*Acer spicatum*).
- Hobble bush (*Viburnum alnifolium*).

FLAT.

The flat type is intermediate between the swamp and the hardwood slope. It includes the low swells adjoining wet swamps, or the gentle lower ridges, and also the knolls in wet swamps. It is fairly well drained, and fern moss replaces sphagnum as the principal ground cover. In essentials it is still the swamp, except that it is drier. Lumbermen, in fact, call it "dry swamp." Here balsam grows rapidly, becomes tall, straight, and clear-boled, attains a fair diameter, and, as in the swamp, often grows pure. But the trees in the dry swamp are much more subject to ground rot than in the wet swamp. When it occurs in mixture its associates are red spruce, yellow birch, and red maple—the two latter small and unimportant. It is on the flats that the heaviest stands of balsam fir are found, and here also it grows more commonly in mixture with red spruce, with which it is cut and marketed for the same uses. Of the four types, therefore, the flat is commercially the most important.

The characteristic ground cover of the flat, in addition to leaf litter (15 per cent), is as follows:

Moss (60 per cent):

Common—

Fern moss (*Hylocomium proliferum*).

Scale moss.

Ferns (5 per cent):

Common—

Spinulose shield fern (*Dryopteris spinulosa*).

Lady fern (*Asplenium felixfemina*).

Flowering plants (20 per cent):

Common—

Wood sorrel (*Oxalis acetosella*).

Bunchberry (*Cornus canadensis*).

Creeping wintergreen (*Chiogenes hispida*).

Clintonia (*Clintonia borealis*).

Sarsaparilla st. (*Aralia nudicaulis*).

Dalibarda (*Dalibarda repens*).

Occasional—

Trillium (*Trillium erythrocarpum*).

Flowering plants (20 per cent)—Continued.

Occasional—Continued.

Chickweed wintergreen (*Trientalis americana*).

Rattlesnake plantain (*Epipactis repens*).

Gold thread (*Coptis trifolia*).

Rare—

Lady's slipper (*Cypripedium acaule*).

Underbrush:

Common—

Hobble bush (*Viburnum lantanoides*).

Withe rod (*Viburnum cassinoides*).

Mountain ash (*Pyrus americana*).

Occasional—

Swamp honeysuckle (*Lonicera oblongifolia*).

Mountain maple (*Acer spicatum*).

Service berry (*Amelanchier canadensis*).

Beaked hazelnut (*Corylus rostrata*).

HARDWOOD SLOPE.

This is the best-drained type. In it hardwood leaf litter, instead of mosses, forms the chief ground cover.

On the slopes balsam fir never occurs in pure stands, but grows scatteringly among red spruce and large-sized hardwoods. The principal species of hardwoods are yellow birch, red maple, sugar maple, and beech. Here balsam fir, provided it is not too heavily shaded, grows rapidly and becomes comparatively large and tall, reaching on the slopes, in fact, its best individual development. It is apt to be very defective, however, and is especially liable to ground rot unless it grows near a brook or spring which furnishes a plentiful supply of water to its roots.

The characteristic ground cover of the hardwood slope besides leaf litter (40 per cent) is as follows:

Mosses (5 per cent):

Occasional—

Plume moss (*Hypnum crista-castrensis*).

Crane moss (*Dicranum fuloum*).

Shaggy moss (*Hylocomium triquitrum*).

Mountain fern moss (*Hylocomium proliferum*).

Fern and fern allies (30 per cent):

Common—

Spinulose shield fern (*Dryopteris spinulosa*).

Shining club moss (*Lycopodium lucidulum*).

Occasional—

Hayscented fern (*Dicksonia pilosiuscula*).

Lady fern (*Asplenium felixfemina*).

Ground pine (*Lycopodium complanatum*).

New York fern (*Aspidium noveboracense*).

Silvery spleen wort (*Asplenium thelypteroides*).

Rare—

Common polipod (*Polypodium vulgare*).

Long beech fern (*Phegopteris polypodioides*).

Flowering plants (25 per cent):

Common—

Wood sorrel (*Oxalis acetosella*).

Bunchberry (*Cornus canadensis*).

Wild sarsaparilla (*Aralia nudicaulis*).

Clintonia (*Clintonia borealis*).

Painted trillium (*Trillium erythrocarpum*).

Flowering plants (25 per cent)—Continued.

Occasional—

Two-leaved Solomon's seal (*Unifolium canadense*).

Sweet white violet (*Viola blanda palustriformis*).

Twisted stalk (*Streptopus amplexifolius*).

Indian cucumber root (*Medeola virginiana*).

Dalibarda (*Dalibarda repens*).

Gold thread (*Coptis trifolia*).

Rare—

Creeping snowberry (*Chiogenes hispida*).

Indian pipe (*Monotropa uniflora*).

Rattlesnake plantain (*Epipactis repens*).

Lady's slipper (*Cypripedium acaule*).

Habenaria (*Habenaria*).

Underbrush:

Common—

Hobble bush (*Viburnum lantanoides*).

Mountain maple (*Acer spicatum*).

Striped maple (*Acer pennsylvanicum*).

Occasional—

Beaked hazelnut (*Corylus rostrata*).

Swamp honeysuckle (*Lonicera oblongifolia*).

Service berry (*Amelanchier canadensis*).

MOUNTAIN TOP.

Higher up the slopes, as the number of sugar maples gradually increases, balsam fir becomes more and more scattering, until it is found only as single specimens here and there, and on the middle slope, the driest portion of the mountain, disappears entirely. Approaching the top, however, at 2,500 or 3,000 feet above sea level, balsam fir reappears, often forming pure stands. Together with black spruce, it is the last to give way to the Alpine flora on mountains rising above timber line.

Conditions on a mountain top, where the prevailing low temperature retards evaporation and helps the condensation of moisture in the air, are similar to those in the swamp, and balsam fir shows much the same development in both places. The chief difference is that on the mountain top the trees are shorter. The principal ground cover is the same sphagnum moss found in the swamps. Balsam fir of the mountain top has no commercial value, because of the difficulty of lumbering it, coupled with its small size and slow growth.

Approaching timber line, balsam fir becomes dwarfed, procumbent, or spreading, with a short trunk and long, horizontal branches spreading near the ground. On the lower surfaces of the lower branches touching the ground, roots are often formed. When such a branch becomes detached from the main stock it may even give rise to an independent tree. The capacity to transform branches into roots has also been observed in balsam fir seedlings that have germinated in wet moss. Often in such cases, as the tree grows larger, additional roots are formed at the lower nodes of the stem beneath the moss, where originally branches grew.

In Michigan, Wisconsin, and Minnesota balsam fir, when growing in mixture with tamarack, arborvitæ or white cedar, spruce, aspen, or black ash, under conditions similar to those existing in the swamps of the northeastern States, is of poor development, with a diameter seldom larger than 11 inches and a height of 30 or 35 feet.

PRESENT STAND AND CUT.

The total stand of balsam fir throughout its range of commercial occurrence may be placed somewhere in the neighborhood of 5,000,000,000 board feet.

TABLE 1.—*Present stand of balsam fir, by States, in million board feet:*

Maine.....	3, 000
New York.....	250
New Hampshire.....	400
Wisconsin.....	395
Michigan.....	200
Vermont.....	110
Minnesota.....	1, 000
Total.....	5, 355

This estimate is undoubtedly very crude, but even a crude estimate seems better than none.

Only within the last four or five years have any records been kept of the cut of balsam fir for various purposes. Growing with spruce, and being used for the same purposes, it always went under the name of spruce.

According to the census reports for 1909, the total lumber cut of balsam fir for the United States for 1909¹ amounted to 108,702,000 feet, and according to the census report for 1910, 132,362 cords, or 66,181,000 board feet, for pulp. The total annual cut of balsam fir in the United States at present is about 175,000,000 board feet. At this rate, the present stand, not counting the increment, will last for about 30 years.

MAINE.

In Maine, balsam fir is most common in the eastern part of the State, especially in the big flat country at the head of the St. John and Penobscot Rivers and their tributaries, and along the coast for about 10 miles inland, where it constitutes nearly one-fifth of the coniferous forests. In the western part of the State, along the Androscoggin and Kennebec Rivers, its proportion in the forest is comparatively small.

From actual measurements by the Forest Service, extended over many hundred acres and upon estimates obtained from persons most familiar with the Maine forests, it is safe to assume that balsam fir constitutes in volume for the whole State not less than 15 per cent of the spruce stand. Based upon an estimate by the Maine forest commissioner in his annual report for 1902, which gives the present stand of spruce as 21,239,000,000 feet, the present stand of balsam fir in Maine approximates 3,000,000,000 board feet.

Replies to circular letters sent out in 1903 by the Forest Service to all saw and pulp mills in Maine, regarding the use of balsam fir, justify the conclusion that about 70,000,000 board feet of this species is being cut annually for pulp and lumber. This estimate is confirmed by the statistics of the Bureau of the Census, which show that in 1910, 32,861 cords, or approximately 16,500,000 board feet,² of balsam fir was cut for pulp in Maine, and that in 1909 nearly 50,500,000 board feet was cut for lumber. This would make the total annual cut of balsam fir in Maine about 67,000,000 board feet. The amount of balsam fir used by the sawmills appears to be proportionately larger than the amount used by the pulp mills. This is undoubtedly due to the great amount of spruce used for pulp. Pulp

¹ The total cut of balsam fir for lumber in 1910 was 74,580,000 board feet, but this figure does not include the cut in the State of New York, and therefore is incomplete. For this reason the figures for 1909 were used.

² In converting cords into board feet, 2 cords are taken to be equal to 1,000 board feet.

manufacturers can afford to pay stumpage prices for spruce which places it almost beyond the reach of the lumbermen. The latter, therefore, must turn more and more to other species, such as hemlock and balsam fir, at least for those purposes for which they will serve as well as spruce.

The amount of balsam fir used by the sawmills has increased within the last 10 years more than 50 per cent, and in some places even 75 or 100 per cent. Ten or 15 years ago, in fact, hardly any balsam fir not large enough for saw logs was cut; now it is taken almost as readily as spruce.

NEW YORK.

In northern New York, balsam fir is abundant in Franklin, Warren, Oneida, Lewis, and Clinton Counties, though it is not lacking in any township throughout the whole Adirondack region. It constitutes at present about 7 per cent of the "spruce" product and about 10 per cent of all the "spruce" pulpwood cut in the Adirondacks. Since balsam fir is now cut for pulp as readily as spruce, and practically no discrimination is made between the two, its proportion in the total output of pulpwood serves to indicate its proportion in the standing coniferous timber. Actual measurements over many acres in different parts of the mountains confirm this representation of balsam fir in the Adirondack forest. A distinction must be made, however, between the numerical and the volume representation of balsam fir. Numerically balsam fir constitutes from 20 to 50 per cent of the total stand, yet, since it never reaches the same sizes as spruce, its proportion by volume must necessarily be less. Based upon figures of the United States Census for 1900 on the stand of coniferous timber in the Adirondacks, the present stand of balsam fir in the Adirondack forests must be between 250,000,000 and 300,000,000 board feet.

The cut of balsam fir in the Adirondacks in 1910 amounted to 33,504,500 board feet, of which 9,248,000¹ board feet were cut for lumber and 24,256,500 board feet (48,513 cords) for pulp. The greater use of balsam fir by the pulp manufacturers than by the sawmills in the Adirondacks is explained by the leading place which New York State occupies in the pulp industry and by the decreased supplies of spruce, necessitating the use of all coniferous timber available for pulpwood.

NEW HAMPSHIRE.

In New Hampshire balsam fir is found mainly in the northern part of the State—in the White Mountains and in upper Coos County. In the southern part of the State it is found in any quantity only in the large swamps around the sources of the Contoocook and Millers

¹ This figure is for 1909; as no figures are available regarding the balsam fir cut for lumber in 1910, it is used as the nearest figure available.

Rivers. Altogether it constitutes about 10 per cent of the total so-called spruce cut for pulpwood in northern New Hampshire and from 1 to 5 per cent in the rest of the State. Since 97.4 per cent of the total cut of pulpwood in New Hampshire comes from the northern portion, 9 per cent may be considered a fair average proportion of balsam fir in the total output of pulpwood in the State.

The percentage of balsam fir used in mixture with spruce in the sawmills varies, according to the location of the mill, from 1 to 20, being largest in Coos County; but for the whole State it probably does not exceed 5 per cent. Thus, about 5,700,000 board feet of balsam fir were cut for pulpwood (1910) and about 12,200,000 board feet for lumber (1909), making a total of 17,900,000 board feet.

Accepting the present stand of softwoods in the four main drainage systems of northern New Hampshire as in the neighborhood of 4,764,000,000 board feet, the present stand of balsam fir in New Hampshire may be estimated in round figures to be 400,000,000 board feet.¹

VERMONT.

In Vermont balsam fir is most common in the northern counties, Caledonia, Essex, and Orange containing nearly 20 per cent of the coniferous forests. In the southern half of the State balsam fir is found in any quantity only in the mountain townships. In 1910 balsam fir made up about $8\frac{1}{2}$ per cent of the total cut for pulpwood and lumber in the State. Assuming that it forms only 7 per cent of the spruce forest, the present stand of balsam fir, based on the census figures for the spruce stand in 1900, must be about 110,000,000 board feet. The annual cut of balsam fir, according to the census report for 1910, is about 12,000,000 board feet, of which about 4,000,000 board feet is for pulpwood and 8,000,000 for lumber.

WISCONSIN.

The only estimate of balsam fir in Wisconsin is that of Filibert Roth,² who placed the total stand in 1897 at 395,000,000 board feet (790,000 cords). In this estimate was included everything from 4 inches up. The yield per acre in all forests where balsam fir occurred was placed at from 50 to 100 board feet, or 4 to 8 cords, per 40 acres, an estimate which agreed with one made by the Chicago & North Western Railway Co. in Forest and adjoining counties. Balsam fir is thinly scattered in most forests of Wisconsin on the more humid loam and clay lands. It is generally less than 12 inches in diameter and below 60 feet in height. Table 2 gives estimates of the stand of balsam fir in the different counties in which it grows.

¹ Forest Service Bulletin 55, Forest Conditions in Northern New Hampshire.

² Forestry Conditions and Interests of Wisconsin, by Filibert Roth. Bulletin 16, U. S. Department of Agriculture, Division of Forestry, 1898.

TABLE 2.—*Stand of balsam fir in Wisconsin, by counties, in million feet board measure.*

Ashland.....	20	Oconto.....	15
Bayfield.....	25	Oneida.....	10
Chippewa.....	20	Portage.....	5
Clark.....	5	Price.....	15
Douglas.....	30	Sawyer.....	25
Florence.....	15	Shawano.....	20
Forest.....	40	Taylor.....	30
Iron.....	15	Vilas.....	10
Langlade.....	30	Wood.....	5
Lincoln.....	25		
Marathon.....	25	Total.....	395
Marinette.....	10		

The cut of balsam fir in Wisconsin for both lumber and pulp is increasing. In 1910, 4,196,000 board feet were cut for lumber and 8,502,000 board feet for pulp, a total of 12,698,000 board feet.

MINNESOTA.

In Minnesota balsam fir is confined largely to the northeastern half of the State, extending south as far as Isanti and Chisago Counties. On moist, retentive soils it reaches a fair development. In the northern counties it attains an average diameter breast high of 10 to 11 inches and an average volume of 51 board feet. Prof. Roth roughly estimated its stand in 1897 as 1,000,000,000 feet. While no cut is indicated for pulp, 10,147,000 board feet were cut in 1910 for lumber.

MICHIGAN.

Balsam fir occurs in the Upper Peninsula of Michigan in mixture with spruce, but there is little prospect of future supply from either species, since they occur scatteringly. Prof. Roth estimated the stand of balsam fir in 1897 at 400,000 cords, or 200,000,000 board feet. The estimates given by Prof. Roth 15 years ago of the stand of balsam fir in the States of Wisconsin, Minnesota, and Michigan were considered by him at that time too low, so their applicability to the present stand in Wisconsin, Minnesota, or Michigan may therefore be justified.

The cut in Michigan is close to that in Wisconsin and Minnesota, amounting to 10,712,000 board feet in 1910; of this, 5,925,000 board feet were cut for pulp and 4,787,000 board feet for lumber.

ECONOMIC IMPORTANCE.

BALSAM FIR PULPWOOD.

Balsam fir finds its greatest economic importance as a pulpwood. There is a close connection between the extent of the available supplies of spruce in a State and the amount of balsam fir used in the manufacture of pulp and paper. As long as there is a plentiful supply of the former, the use of balsam fir is naturally restricted.

But where the demand for pulpwood is greater than the available supply of spruce, balsam is the accepted substitute. Out of about 2,220,000 cords of domestic coniferous wood used in the United States by the pulp industry in 1910, 6 per cent, or 132,362 cords (about 66,000,000 board feet), was balsam fir.

The Forest Service, in 1903, sent a circular letter inclosing a series of questions to the pulp and paper manufacturers, lumbermen, town supervisors, and surveyors in States in which balsam fir occurs. Nearly 100 answers were received from pulp and paper mills, which throw much light upon the place of balsam fir in the economy of paper making. About 70 per cent of all the mills that reported use balsam fir in quantities varying from 2 to over 30 per cent of all the pulpwood consumed. The reasons given by those who do not use it are either that they can not get it, or that they do not like to use it "if they can detect it," or that they use some other species exclusively. The amount of balsam fir used by each mill varies from year to year, nor can it always be accurately ascertained at the mill. Spruce and balsam are invariably kept together, and the latter, after it has been barked and kept in water for any length of time, can not be readily distinguished. In general, it can be said that a greater percentage of balsam fir is used by the mills of New York (48,513 cords) than by those of Maine (32,861 cords). This is due partly to the ranking position occupied by the State of New York in the pulp industry and its relatively large number of sulphite mills capable of using an unlimited amount of balsam fir and partly also to the comparatively large supplies of spruce in Maine.

OBJECTIONS TO THE USE OF BALSAM-FIR FIBER.

The principal objection to the use of large amounts of balsam fir in the ground-pulp process is said to be on account of the pitch that covers the felts and cylinder faces. It is admitted by nearly all pulp and paper men that from 10 to 25 per cent of balsam can be used in ground pulp without lowering the grade of the paper produced. A few go even so far as to claim that a larger admixture of balsam fir—from 20 to 25 per cent—is of advantage, in that it makes the pulp "free"; that is, separates the spruce fibers during the manufacturing process and in this way allows the water to be easily drawn from the sheet. Still others claim that a satisfactory ground wood pulp can be made almost entirely of balsam. In chemical pulp, because of the acids dissolving the pitch, any amount of balsam can be used, though some claim that paper made of pulp containing a large admixture of balsam lacks strength, snap, and character. The pitch gives most trouble in freshly cut balsam, while in wood soaked in water over a season the amount is so small that it need not be taken into account. Some of the larger mills claim that after balsam fir has remained in the pond for one year any amount of it can be used.

RESIN CONTENTS.

The complaints against the larger amount of pitch in balsam fir are somewhat strange in view of the fact that the actual resin content of balsam fir is less than that of spruce. Resin in coniferous wood occurs normally in cells, of which the wood is built up as a house is built of bricks, and in the spaces between the cells, known as resin ducts, running vertically and horizontally through the wood. These resin ducts may be seen on cross sections of freshly cut wood as whiter or darker spots marked by exuded droplets of resin. On radial and tangential sections the ducts appear as fine lines or dots of different color. The difference in resin content of the different genera and species of the conifers depends mainly upon the number and size of their resin ducts. Balsam fir is one of the few conifers that lack resin ducts entirely, a thing which serves readily to distinguish it from the spruces and pines. Resin is found in the wood of balsam fir only in the interior of the cells, where it occurs in the form of small droplets. The bark of balsam fir is very rich in resin, but after the former is rossed off the wood should be freer of resin than spruce, which contains resin ducts and resin cells. Therefore the pitch, which according to all reports is the greatest drawback to balsam pulpwood, must either come from the resin in bark left on the surface of the block or else is formed in the process of grinding, in which case it is not of a resinous nature. In either event, the presence of pitch is apparently not due to any property of the wood itself.

A chemical determination of the resin contents of six spruce and of four balsam-fir sections made by the Bureau of Chemistry, United States Department of Agriculture, in 1904, gave the following results:

TABLE 3.—*Resin contents of spruce and balsam fir.*

SPRUCE.				
	Moisture.	Non-volatile resins.	Volatile resins.	Total amount of resins.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Top.....	5.60	0.88	0.23	1.11
Middle section.....	5.66	.92	.67	1.59
Butt section.....	6.39	.76	.49	1.25
Top.....	5.85	1.36	.27	1.63
Middle section.....	5.57	2.33	.50	2.83
Butt section.....	5.62	1.48	.34	1.82
Total.....				10.23
Average.....				1.70
BALSAM FIR.				
Butt section.....	5.31	1.23	0.19	1.42
Middle section.....	5.06	.58	.15	.73
Butt section.....	5.01	.77	.19	.96
Middle section.....	4.80	.67	.48	1.15
Total.....				4.26
Average.....				1.06

Though the inferior quality of wood pulp containing a large amount of balsam fir can not be denied, it is probably not altogether due to the inferiority of the balsam wood, but to deficient knowledge of how to properly manufacture it into paper.

WORKING UP BALSAM FIBER.

There is no doubt that the fiber of balsam fir is weaker, shorter, and softer than spruce fiber; therefore the prevailing practice of working up balsam fir with spruce in both mechanical and chemical processes ordinarily results in an inferior grade of pulp, if the admixture of balsam is considerable. This is not so perceptible in the sulphite process as in the ground pulp. The wood of balsam fir, being softer, cuts more easily than spruce wood; therefore a stone of a sharpness and at a given pressure to produce good strong pulp from spruce makes poor pulp from balsam fir. With dull stones and light pressure a better quality of pulp could probably be made from balsam. Similarly, in the case of chemical pulp better results could most likely be obtained if weaker acids more suitable to the softer nature of balsam-fir fibers were used. The different properties of wood of spruce and that of balsam fir naturally suggest a different treatment of their fibers, which could best be accomplished by handling them separately. Experiments in this direction would probably open a much larger field for the use of balsam pulpwood than it now has.

SMALL YIELD OF WOOD FIBER.

Another drawback to balsam as compared with spruce is its smaller yield in pulp and paper per cord of wood. Being lighter than spruce when seasoned, it contains less wood substance per cord and so yields a smaller amount of pulp. The following figures regarding the yield of chemical and mechanical pulp per cord of spruce and balsam are based on actual experience and may be considered as average:

	Ground pulp.	Chemical pulp (sulphite).
	<i>Pounds per cord.</i>	<i>Pounds per cord.</i>
Spruce.....	1,800	1,200
Balsam fir.....	1,500	1,000

This drawback, however, would not exist if the stumpage price of balsam pulpwood were proportionately lower than instead of being nearly the same as that of spruce. Some mill men even claim that the only objection they have against balsam fir is its smaller yield in pulp, which, at the same stumpage price as spruce, makes its use unprofitable and discourages any attempts to improve methods of utilizing or manufacturing it.

UN SOUNDNESS.

In comparison with spruce, balsam is a short-lived tree, and is apt to become defective by the time it reaches large size. A log from a large tree which may seem apparently sound will, when cut up into blocks, often show heart rot in some portion of its length, or, still more frequently, the fibers at the center will be of soft texture, making its use uneconomical. Decayed heart is not so common in young, small-size trees, and since small logs contain more sap and produce better fiber than large ones, balsam of small diameters is not only suitable for pulpwood, but is to be preferred to the large sticks.

Knots, though more numerous in small sticks than large ones, are not a serious objection. They can be cheaply removed by passing the chipped wood through a tank of water, in which the knots sink and the wood is carried off from the surface.

Balsam fir cut in winter produces firmer and harder paper than when cut in summer.

The general tenor of nearly all the answers to the circular letter was that balsam fir is undoubtedly inferior to spruce in every respect, but that it has come into the pulp industry to stay. It fills a place in the economy of paper making, and its drawbacks are of such a nature that they may be to a great extent, if not entirely, overcome by intelligent effort.

BALSAM FIR LUMBER.

The increased demand for spruce by pulp men, who were able to pay higher prices for it than the lumbermen, compelled the latter to turn their attention to hemlock and balsam. Hemlock enters now more and more into building operations, supplanting spruce; while balsam fir, not being as strong as spruce, is relegated to uses for which strength is not a prime requirement. The total cut of balsam fir for lumber in 1909 was reported as 108,702,000 board feet.

Balsam fir is softer and more brittle than spruce; it decays rapidly in the ground, and when green does not hold nails well; but being light and tasteless it makes a very desirable box material, especially for foodstuffs. It is extensively used for cheese-box headings, staves for fish and sugar barrels, sardine cases, butter boxes, and the like. It is easily worked, and is well adapted for molding, novelty, bevel, and drop siding. It is of straighter grain than spruce, and in seasoning is less subject to warping and twisting, which makes it the better of the two woods for fence boards, small joists, planing, scantling, laths, and shingles. Its white color often makes it desirable for house finishing, and some consider it superior to spruce for violins. It saws easier, dries quicker, and is claimed to hold paint better than spruce. It has also been found to be suitable for rough lumber, flooring, ceiling, studding, crating, furniture, sheathing, children's carriages, toys, small frames, matches, square timber, excelsior, etc. In the form of

box boards it yields about 10 per cent of material more to the cord than does spruce.

In 59 out of 141 sawmills which answered the circular letter, the use of balsam fir in the past few years has not perceptibly increased. Thirty-four mills now use from 10 to 40 per cent more than formerly, 30 mills from 40 to 75 per cent more, 13 mills from 75 to 100 per cent, while 2 mills use four times as much as they used three or four years ago. Only three mills report that the amount of balsam used by them has decreased.

LUMBERING BALSAM FIR.

In the Adirondacks, as well as in Maine, New Hampshire, and Vermont, the methods of cutting balsam and spruce for pulpwood differ somewhat from those used in getting out saw logs. Pulpwood is cut largely in summer and autumn, and is usually limited to a diameter of 8 inches on the stump and to 4 inches in the top. The trees are sawed close to the ground, the stump height seldom being over 1 foot. The logs are usually cut in lengths of 4 feet.

ADVANTAGES OF CUTTING INTO 4-FOOT LENGTHS.

Cutting into 4-foot lengths, when the drive is short and the stream shallow, has decided advantages over cutting long logs. The short sticks dry better, and for this reason few are lost through sinkage during the drive—a loss more common with balsam than with spruce. Green balsam logs do not float readily, and on a long drive may become water-logged and sink. Balsam logs, apparently sound at both ends, often contain rot in the center, and by having them cut into short lengths the buyer of pulpwood guards himself against defects. The owner of the forest, too, gains by cutting into short lengths, since it allows a fuller utilization of each individual tree. Thus, if the merchantable length of a tree that can be used for pulp is 22 feet, and the logs are cut into 12, 14, and 16 foot lengths, the most that could be used in such a case is a 16-foot log, leaving the remaining 6 feet to waste. On the other hand, by cutting into 4-foot lengths, two-thirds of the 6 feet would be turned into useful material. On a large cut this sort of waste may be considerable. It is true the short logs in the water will not support a man's weight, and so in many places are harder to drive, but since they seldom form jams and a smaller volume of water is needed to float them, the cost of driving 4-foot sticks for short distances is less than the cost of driving long logs. In one particular case, by changing the log lengths from 12 feet to 4 feet, the cost of driving over the same distance has been reduced from 44 cents to 10 cents per cord, besides lessening the loss through sinkage and undetected defects.

DIFFICULTIES IN LOGGING.

Compared with spruce, balsam fir is difficult and expensive to log. It is small, and therefore a gang working in a pure stand of balsam can not cut in a day as much as when working in spruce. When green it is heavier than spruce and therefore harder to snake out and handle, especially in summer in the swamps. It yields a greater per cent of cull, and in many cases the presence of rot can not be detected until the tree has been felled and cut into. It floats heavily, and many logs become water-soaked and sink, making the driving very difficult. To offset these disadvantages, and to make the use of balsam more profitable, its stumpage price should always be lower than that of spruce.

STUMPAGE PRICE AND LOGGING COSTS.

NEW YORK.

The ruling price in the Adirondacks for cutting and skidding pulpwood (long logs) is about \$1.50 per cord. In this price the cutting of roads is included. The extra cost of resawing the long logs into 4-foot lengths and piling them along the log road is ordinarily 40 cents per cord, and requires, in addition to the regular crew of six men, two sawyers on the skidway. The logs, which in such cases are cut into lengths that are multiples of 4—as 12, 16, and 20—are snaked to the skidway, where they are sawed into 4-foot sticks and piled. A gang of eight men will cut, resaw, and pile from 9 to 12 cords per day. In cutting 14-foot lengths a gang of six men will cut and skid from 14 to 16 cords a day. The price of hauling varies with the distance. For two or three trip hauls per day, with 2 to 3 cords per sled, the charge is ordinarily \$1.60 per cord. If the distance is short and several trips are possible the price is less. The stumpage price is a very variable quantity, ranging all the way from \$2 to \$3.50 per cord. Such pulpwood is supposed to contain, besides spruce, 10 per cent of balsam and 10 per cent of hemlock. As a rule, however, the percentage of balsam runs much higher. Since balsam pulpwood is hardly ever bought by itself, the price could not be determined, but it is probable that pure balsam pulpwood would command from 50 cents to \$1 per cord less than the ordinary pulpwood now offered on the market. The average cost of driving can hardly be ascertained, being dependent upon the kind of stream, distance, number of logs, etc.

MAINE.

In Maine balsam fir is taken for pulp along with spruce, the only requirements being sufficient size and soundness. The scaler culls balsam closer than spruce. While a good deal of pulpwood is cut in

winter and sawed into 4-foot sticks, which are piled and later hauled to water or rail on sleds, there is generally no difference in the methods of logging for pulp or lumber, except, perhaps, that the former is marked by closer utilization. The trees are usually cut down and topped off with the ax. Stumps run from 1.5 to 2 feet in height; most are cut pretty close to the root swelling. Logs may be even lengths up to 40 or 50 feet. In a pulp cut, however, the lengths are not carefully measured.

The stumpage price of balsam when not cut with spruce is in the neighborhood of \$3.50 per 1,000 board feet, while spruce stumpage ranges from \$4 to \$7, a conservative average being about \$5. Timber more than one-half mile from a landing is yarded; that is, put in piles of 20,000 to 50,000 board feet, and is hauled in February and March, when the snow is good. Hauling costs 50 cents per 1,000 board feet per mile. In addition, it takes four men at the yard to shovel snow off the piles and help load. Three men are required at the landing to mark and roll the logs. Each logger within one-half mile of a landing hauls as many logs as possible direct to the landing without yarding; this saves the cost of handling the logs twice. Thus, while the cost of hauling direct to the landing may not be over \$4 per 1,000 board feet, yarding and then hauling increases the cost of getting out the logs to the landing to about \$7 per 1,000 board feet. This cost, however, varies with the number and size of the logs, the distance to drag or haul, and the ease with which the timber can be reached. Dense undergrowth, necessitating the addition of one or more swamper to the crew, will, for instance, increase the cost of getting logs to the landing.

From \$6.50 to \$7 ought to cover, on an average, the cost of getting logs to the landing. Long drives, interrupted by large stretches of dead water, make driving an important item in Maine. There are two kinds of log drives, brook and river. In a brook drive the logs are driven by the individual lumberman; river driving is done by a corporation composed of the lumbermen who have logs in the river.

Balsam is driven along with spruce and, except for its greater sinkage on long drives, behaves in almost the same way. It seldom causes a jam, for if a balsam log gets crosswise in a bad place it usually breaks. Spruce, on the other hand, would hang and perhaps start a jam.

NEW HAMPSHIRE AND VERMONT.

In New Hampshire and Vermont methods of logging essentially resemble those of Maine, but in places acquire some of the New York features of pulpwood cutting. Occasionally both are modified to meet local conditions.

WEIGHT PER CORD OF BALSAM FIR AND SPRUCE.

In order to ascertain roughly the weight of a cord of green and dry balsam and spruce pulpwood, five balsam firs and five spruces were felled, and three sections, each equal to a quarter of a cubic foot, were taken from the bottom, base of the crown, and top of each tree, and their weights determined at the time of cutting, and again two weeks and three weeks later. From these weights the average weight of 1 cubic foot of green and half-seasoned spruce and balsam wood was obtained. At the same time balsam and spruce were piled separately, and the actual cubic contents of solid wood in a cord determined. By multiplying the average weight of 1 cubic foot of green and half-seasoned balsam and spruce by the number of cubic feet of solid wood in a cord the weight of 1 cord of green and half-seasoned balsam and spruce pulpwood was obtained. From figures for weight per cubic foot given by Prof. C. S. Sargent, the weight of 1 cord of air-dry balsam and spruce was determined, respectively, as 2,252 and 2,662 pounds. The results of the different weighings are presented in Table 4.

TABLE 4.—*Weight per cubic foot of spruce and balsam fir.*

No. of tree.	Green (Sept. 5).		Half seasoned (Sept. 26).	
	Spruce.	Balsam.	Spruce.	Balsam.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
I.....	49.00	52.00	35.25	37.06
II.....	50.75	52.25	30.75	36.25
III.....	44.75	55.00	30.50	37.75
IV.....	51.00	51.25	35.00	34.00
V.....	44.25	46.00	32.00	32.00
Average weight per cubic foot.....	48.15	51.30	32.70	35.41
Average weight per cord.....	4,543.00	4,858.00	3,094.00	3,354.00

Thus, balsam weighs about 7 per cent more than spruce when green and 18 per cent less when dry. The sections taken from the butts of the trees weighed the least; the sections from the tops were the heaviest, due undoubtedly to the proportionately greater amount of sap and larger number of knots in the tops. Pulpwood never becomes entirely dry in the woods, and though by the time balsam is drawn to the river it loses about 30 per cent of its weight, it is still probably from 5 to 6 per cent heavier than spruce.

MEASURING PULPWOOD.

In the Adirondacks pulpwood is now measured almost exclusively by the cord. A cord contains 128 cubic feet of stacked wood, represented by a stack 4 feet high, 4 feet wide, and 8 feet long. In order

to find the number of cords in a stack of other dimensions the length of the stack is multiplied by its width and height, and the result divided by 128. Thus, a stack 4 feet high and 8 feet long made of 12-foot logs contains 3 cords, the same as a stack 4 feet high and 24 feet long made of 4-foot sticks.

CONDITIONS AFFECTING THE SOLID CONTENTS OF WOOD IN A CORD.

LENGTH.

Though the number of cubic feet in both stacks is the same, the actual contents of solid wood is not. Logs are never entirely straight and smooth, and between them in the pile are cracks which increase in size with the length of the sticks. Thus, if 3 cords of 12-foot logs were resawed into 6-foot lengths there would not be enough wood to measure 3 cords, or a stack 4 feet high and 16 feet long. The stack would be smaller and the shrinkage even greater were the 12-foot logs resawed into 4-foot lengths. Thus, the shorter the stick the more wood is required to make a given number of cords. Careful investigation abroad showed that the difference in the solid contents of a cord made of 12-foot logs and one of 4-foot sticks amounts to at least 6 per cent. Pulpwood in the Adirondacks is cut mostly into 4, 12, and 14 foot lengths. It ought, therefore, to be of great practical interest to the owner of a forest tract, as well as to the buyer of pulpwood, whether the wood is cut and stacked into 4 or 12 foot lengths. Twenty thousand cords are frequently cut from a single tract during one year, and the choice of 4 or 12 foot lengths means a difference of 1,200 cords, or, in money (at stumpage price of \$2.50 per cord), of \$3,000.

DIAMETER.

The diameter of the logs also has a decided influence upon the volume of solid wood in the stack. The smaller the logs the less the amount of wood, for the more sticks in the cord the greater is the number of cracks. The difference in solid volume of two stacks, one composed of sticks twice as large as those in the other, may amount to 13 per cent, and if of sticks four times as large to even 25 per cent. From 6.26 cords of pure balsam fir pulpwood, cut into 4-foot lengths, all sticks 7 inches and below in diameter at the upper end were selected and piled separately from the sticks with a diameter of more than 7 inches. To find the volume of solid wood in the two stacks the volume of each 4-foot stick was determined. The stack made of logs 7 inches and less in diameter averaged 116 sticks and 91.4 cubic feet of solid wood per cord. The stack made of logs above 7 inches in diameter averaged 56 sticks and 95.75 cubic feet, or 5 per cent, more of solid wood per cord. In another case 8.68 cords of balsam, piled and measured in the same way, gave relatively similar results.

FORM.

The smoother and straighter the logs the fewer the air spaces between them, and consequently the greater the solid contents of the stack. For this reason the clear trunks of trees yield more solid wood per given space than the tops.

SEASONING OF WOOD.

As freshly cut wood dries in the air the stack shrinks, resulting in an increase of solid wood per given space. In drying, it is true, the wood cracks, and the bark becomes detached, which tends to counteract the shrinkage of the stack, but not enough to neutralize it entirely. It therefore makes a difference how soon after felling the stack is measured. Softwood in thorough air-drying shrinks from 9 to 10 per cent, consequently stacks of dry softwood have from 9 to 10 per cent more of solid volume than similar stacks of green wood.

MANNER OF PILING.

The volume of solid wood in the stack is also affected by the way it is piled and fixed. The higher the stack, the less closely it can be piled and the less wood it will contain per given space. Stacks higher than 4 or 4.5 feet can not be piled conveniently. The heavier the log the less close is the piling and the less solid wood there is in the cord. In order to hold the pile together one or two stakes are used at each end. The volume of solid wood per cord is higher when one stake is used at each end of the stack than when two stakes are used, since in the latter case the ends of the sticks can not reach much outside the stakes. There always remains some space between the stakes and the wood, so that the fewer the stakes used for the total amount of wood corded (i. e., the longer the stacks), the higher is the solid volume per cord. Efficiency of labor, moreover, has its effect. If the branches are not trimmed close to the body of the log, if the logs are chopped instead of sawed, if the laborer is careless in piling, there is less solid wood per given space.

HOW THE STACK SHOULD BE MEASURED.

The length of a stack should be measured half way up from the ground, since the top is usually longer than the bottom, due to the spreading of the end stakes. The top length would give more and the bottom length less than the actual solid volume. The height of the stack, which is seldom uniform, should be measured at several places on both sides, and the average taken.

ACTUAL SOLID CONTENTS OF CORDS OF DIFFERENT LENGTHS AND DIAMETERS.

No correct comparison can be made, then, between stacks containing the same number of cords, but composed of logs of different lengths, diameters, or shape, unless the actual solid volume of the

two stacks is known. Only by knowing this can one avoid paying the same amount of money for different amounts of solid wood. Table 5 gives the solid volume of wood in a cord according to size and length of the sticks. Other factors which influence the solid contents are variable, and are therefore not considered. Sticks with a diameter of more than 7 inches at the upper end are usually derived from the lower part of the trunk, are free from branches, and cylindrical in shape. Sticks less than 7 inches in diameter come usually from the upper parts of the trees. The mixture of these two classes is typical of most of the pulpwood offered on the market.

TABLE 5.—*Volume of solid wood per cord.*

Length.	Small diameter over 7 inches.	Small diameter from 7 to 4 inches.	First and second classes mixed.
<i>Feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>
4	96.7	92.4	94.9
8	91.6	87.2	89.7
12	86.2	81.6	84.3
16	80.2	75.5	78.3

Table 5 is presented as a basis for specifications in contracts for pulpwood. Designating the money value of 1 cord of 4-foot logs of the third class as 100, the value of 1 cord of logs of the lengths and diameters given in table 6 will be as follows:

TABLE 6.—*Relative money value of cords composed of logs of different lengths and diameters.*

Length.	Small diameter over 7 inches.	Small diameter from 7 to 4 inches.	First and second classes mixed.
<i>Feet.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4	101.8	97.4	100.0
8	96.6	91.9	94.6
12	90.9	86.0	88.9
16	84.6	79.6	82.6

LIFE HISTORY OF BALSAM FIR.

GENERAL APPEARANCE.

Balsam fir (*Abies balsamea* (Linn.) Mill.) is a small evergreen tree, seldom reaching, in the State of New York, a height of 85 feet and a diameter of 18 inches breast high. (Plate I.) In Maine occasional trees attain a height of 95 or 100 feet and a diameter of 25 or 30 inches. As a rule, however, mature trees are from 12 to 16 inches in diameter and from 70 to 80 feet high. Of all the northern softwoods, balsam fir is probably one of the most symmetrical trees. The bole has a very uniform and gradual taper closely resembling a cylinder in form.

The crown of a normal tree is always conical, since the lower branches are longer than the upper ones. The main branches are arranged in whorls of 4 to 6, with here and there scattered solitary branches between. The lower branches of a mature tree are long, slightly pendulous, those near the middle of the crown horizontal, and the upper short branches ascending. As with white pine, the branches readily die off, but remain on the trunk for a long time. The crown, therefore, may begin very high up the tree, but the clear length in the lumberman's sense is comparatively short. This explains to a large extent why balsam-fir lumber has, as a rule, more knots than spruce lumber.

FOLIAGE.

The needles differ in shape and arrangement, depending upon their position on the tree. They are sessile, narrow, linear, notched at the apex, and from half an inch in length on the upper branches to an inch and a half on the lower ones. On the lower branches, while actually spirally arranged, they are twisted so as to form but two rows, horizontally spread on each side of the branch. On the upper branches they retain their ascending spiral arrangement. They are dark green above and silvery white beneath on account of the many stomata which are arranged in lines and appear as minute, shiny dots, and are especially conspicuous in newly formed leaves. This arrangement of both branches and foliage is simply a response of the tree to light conditions. The top of a tree normally receives light from all sides, and needles and branches, therefore, stand out in all directions. At the bottom of a tree in the forest light comes mainly from above, hence the branches and needles there are arranged in a horizontal plane with their functional surface upward. Trees that are suppressed have feathery and spray-like foliage, also due to light conditions.

The foliage of balsam fir persists for from 8 to 13 years, depending upon the amount of shade and the thriftiness of the tree. Dense shade and rapid growth cause the needles to drop earlier; abundance of light and slow growth allow them to remain on the tree for a longer time.

LEAF STRUCTURE.

The leaf structure of balsam fir, as of the entire genus *Abies*, is very similar to that of the pines. It consists of three parts—the outer or cortical part, the chlorophyll-bearing or mesophyll part, and the fibro-vascular part. The outer part is composed of an epidermis and strengthening cells lying directly beneath. The chlorophyll part is composed of parenchyma cells, among which are distributed the resin ducts. These ducts either lie directly beneath the epidermis close to the periphery of the leaf surface or else are surrounded

by the parenchyma nearest to the center of the leaf. In the former case the ducts are termed peripheral; in the latter, medial. The fibro-vascular bundles lie in the center of the leaf and are surrounded by an imperfect bundle sheath.

The leaf structure affords a reliable means for distinguishing one species of fir from another. Only Alpine fir (*Abies lasiocarpa*) and Fraser fir (*Abies fraseri*) are likely to be confused with balsam. The range of balsam touches that of Alpine fir in the West and that of Fraser fir in the South. These three species are readily distinguished

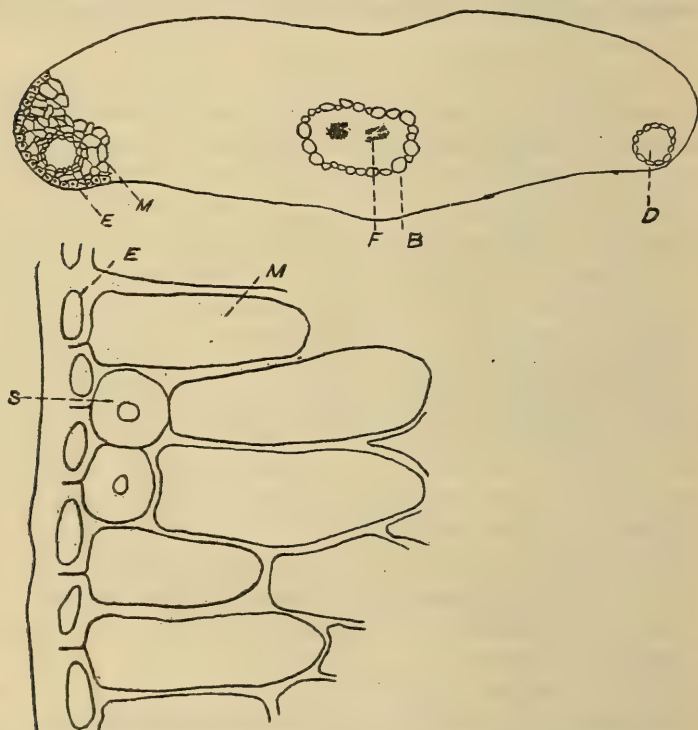


FIG. 2.—Leaf structure of *Abies grandis*: *D*, ducts; *B*, bundle sheath; *F*, fibro-vascular bundle; *M*, mesophyll; *E*, epidermis; *S*, strengthening cells.

from the rest of the firs, such as *Abies grandis* (fig. 2) and *Abies concolor*, by the position of the resin ducts. In balsam fir (fig. 3), Alpine fir (fig. 4), and Fraser fir they lie nearer the center, while in the other species they lie close to the periphery of the leaf, as observed by cutting through a fir needle and observing the exudation of the resin. Balsam is distinguished from Alpine and Fraser fir by the presence of only a few or the entire absence of strengthening cells, which, in the two other species, occur in considerable number.¹

¹ The Resin Ducts and Strengthening Cells of *Abies* and *Picea*, by Herman B. Dorner. Proceedings of Indiana Academy of Science, 1897, p. 116.



BALSAM FIR, ADIRONDACKS, NEW YORK.

BARK.

The bark on the stump of a mature balsam fir is seldom thicker than 0.7 of an inch and in the top, at a diameter of 4 inches, seldom more than 0.3 of an inch. In volume the bark amounts to about 10.5 per cent of the whole tree. On thrifty trees it is very smooth, except for swellings or "blisters," which contain a clear liquid from which the so-called Canada balsam is obtained by distillation in water. In abundant seed years balsam blisters are very small, probably due to the tree's use of most of the foodstuffs for the production of seed. Abnormally thick, rough, or scaly bark of an ashy color, accompanied

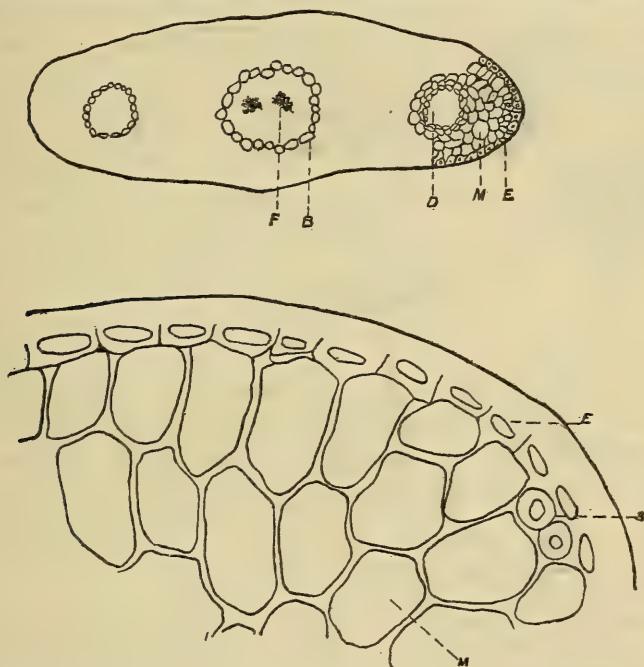


FIG. 3.—Leaf structure of *Abies balsamea*: D, ducts; B, bundle sheath; F, fibro-vascular bundle; M, mesophyll; E, epidermis; S, strengthening cells.

by swelling of the bole, is an almost infallible sign that the tree is rotten at those parts. The natural color of the bark in young trees is a dull, faded green, mottled with patches of gray. With age the bark becomes entirely gray and slightly scaled, but not the dull ashy gray of a defective tree or the shaggy moss and lichen-covered scale of a slow-growing balsam in the swamp.

ROOT SYSTEM.

Whether grown in deep or shallow soils, balsam fir produces a very superficial root system, penetrating to a depth of about 2 or 2.5 feet. Taproots, if developed at all, soon die and rot away, especially in

soils lacking an abundance of moisture, and often become points of entrance for destructive ground rot. The strongly developed lateral roots extend horizontally in all directions for a distance of 4 or 5 feet, and even more. The bark of the roots is bright red and comes off in thin scales.

FLOWERS.

The female and male flowers (cones) occur on the same tree in the top at the outermost ramifications of the branches. The female flowers occupy the extreme top near the ends of the upper branches and are borne perpendicularly in the leaf axils on the upper sides of

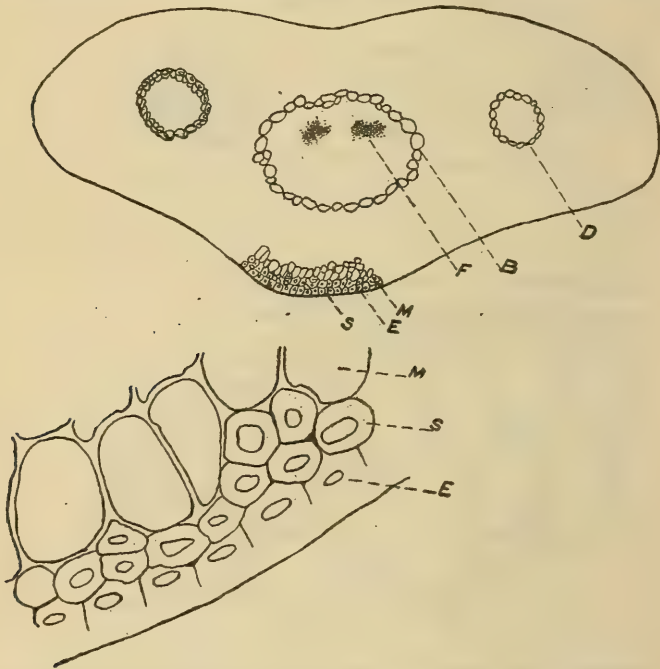


FIG. 4.—Leaf structure of *Abies lasiocarpa*: D, ducts; B, bundle sheath; F, fibro-vascular bundle; M, mesophyll; E, epidermis; S, strengthening cells.

the previous year's branches, while the male flowers are borne mostly on the under or lower sides. The cones, which are violet in color, cylindrical shaped, and from 2 to 4 inches long, do not turn downward after fertilization, like the cones of spruce, but remain erect. They ripen in one year, about the end of September. The mere opening of the erect cones does not liberate the seeds, but the flat, smooth scales of the cone and the scale bracts themselves drop off, carrying the seed with them, and leaving the axils of the cone on the tree for years. The deciduous scales of the cone are broad, round at the top, and narrow to a wedge at the bottom. Within each scale are two

winged seeds. Outside of each scale, at the bottom, is a bract¹ resembling a transformed, winged fir leaf, the end of which, on a mature cone, seldom protrudes enough to be noticed. These bracts furnish a means of distinguishing balsam, Fraser, and Alpine fir. In general, the relative lengths of the cone scale and this bract are means to distinguish between the different native firs, but in the case of balsam the value of this distinction is lessened because of the occurrence of forms with slightly exserted or protruding bracts.

The classification of Fraser fir as a distinct species rests not on the protrusion of the bract, but on its spatulate and reflexed form. The forms of balsam fir with slightly exserted bracts need not, therefore, cause any confusion, for though these do protrude a little, they are not different in shape from the included form, and are neither spatulate nor reflexed. (Fig. 5.)

Since the bracts of Alpine fir never protrude, this variant character in balsam is of value in distinguishing it from Alpine fir. Furthermore, the cone scale of Alpine fir is larger than that of balsam, as shown in Fig. 5 (*b* and *c*).

This distinction, however, can not always be relied upon, because the size and form of the cone scales of Alpine fir vary. It is safer, therefore, to distinguish Alpine from balsam fir by the form of the bract, which in the former is conspicuously long pointed.

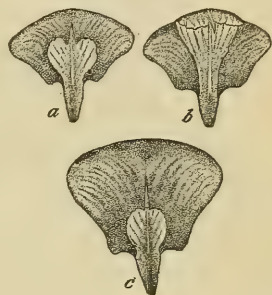


FIG. 5.—Cone scale and bract, natural size: *a*, *Abies balsamea* (L.) Mill.; *b*, *Abies fraseri* (Pursh.) Lindl.; *c*, *Abies lasiocarpa* (Hook.) Nutt.

REPRODUCTION.

Under favorable conditions balsam fir bears fruit when about 20 years old and 15 feet high. Regular production of seeds, however, does not begin before the age of 30 or 35 years. On high mountains, above timber line, scrubby balsam begins to bear seeds in large quantities when from 23 to 25 years old. The amount of seeds borne by individual trees depends, of course, on the size of the crown. As a rule trees in a dense stand bear less seed than trees in the open. In a mixed forest the dominant trees are prolific seeders, the intermediate trees moderately so, while the suppressed trees produce no seed at all. Although balsam fir produces some seed every year, plentiful seed years occur only at intervals of two, three, and even four years.

¹ Discussion and Drawings of Cone Scales and Bracts, by William H. Lamb, Forest Service.

FREQUENCY OF SEED YEARS.

An investigation of the ages of seedlings on several reproduction plots in the Adirondacks revealed the fact that of the total number counted the per cent of ages from 1 to 11 years was as follows:

	Per cent.
1 year old (1902).....	46.1
2 years old.....	.0
3 years old.....	.2
4 years old.....	1.2
5 years old (1898).....	51.1
6 years old.....	.1
7 years old.....	.1
8 years old.....	.5
9 years old.....	.2
10 years old.....	.3
11 years old.....	.2

The large representation of seedlings 1 and 5 years old serves to indicate an occurrence of plentiful seed years in the Adirondacks at intervals of four years.

Other seed years can not be readily determined by this study, since the seedlings after reaching an age of 6 years do not stand the dense shade very well, and few survive. In Maine a similar study has shown the occurrence of good seed years every other year. In one instance the seed years were traced back to 1882, all of them occurring in the even years. In New Hampshire good seed years were found to occur every third year.

QUANTITY AND QUALITY OF SEED.

As determined by the Forest Service, the number of seed per pound averages about 36,000; the weight of a thousand seeds, 0.39 ounce (12.4 grams); and the germination per cent, from 20 to 30.

* GERMINATION.

Since the seeds are scattered late in the fall, when frosts have already occurred, they lie dormant through the winter and come up the next spring. Hardwood leaf litter, duff, moss, mineral soil, rotten logs—all present an equally good germinating bed, if moist. Balsam differs from spruce in this respect, requiring more moisture, as may be inferred from the fact that spruce seedlings are found in drier situations, both on logs and on the ground. A rather dry and high log will have plenty of spruce seedlings and very few balsam, while a well-rotted moist log will have a great number of balsam seedlings. The same is true of stumps.

The number of seedlings that come up on the acre varies with the type of forest. Thus on the hardwood slopes in the Adirondacks,

where balsam fir occurs scatteringly, the number of seedlings per acre is small, often only 700 to 1,000, though occasionally, if there are a number of large balsams, the number may reach 50,000. The number of seedlings is, of course, largest in pure stands of balsam, where they may be 300,000 and more to the acre. In mixture with spruce in the swamps and flats the number of balsam seedlings will vary from several thousand to 200,000 and more, according to the number of large seed-bearing balsams in the stand.

TOLERANCE.

Balsam fir requires less light than tamarack, white pine, and white cedar, but more light than either red spruce or hemlock. It will, however, endure more shade on deep, moist soils than on poor, shallow ones. In mixture with spruce, mature healthy balsam invariably towers above the former. Similarly, in a mixed hardwood forest, balsam fir, when fully developed, is the dominant tree. For the first five or six years of its life, balsam will grow in dense shade, but as it develops it demands more and more light. On moist soils, however, it may thrive without being in the top story of the forest, and beneath white birch and poplar, also, it often remains apparently healthy and vigorous. But where it comes in under a hardwood forest already established, its leader is usually stunted or killed when it enters the hardwood foliage. A broken limb or leader often affords the means of entrance for rot, and though balsam, especially on deep, moist soil, is capable of recovery after a long period of suppression, it is apt in such cases to be unsound. Many trees were found to be rotten in the middle at the point of suppression, with no visible point of entrance for the rot. Others were found 100 years old, with a height of 18 feet and a diameter of 3 inches, which, after 66 years of suppression, retained sufficient vitality to grow rapidly after again receiving the light.

SOIL AND MOISTURE REQUIREMENTS.

Though their demands upon soil are very similar, balsam fir requires for its best development a richer and moister soil than does spruce. With its more northern distribution it seeks the cool and moist north and east slopes in preference to other exposures. In the Adirondacks it is hardly ever found on the abrupt, rocky, southwest slopes, with thin soil, on which spruce often forms a pure stand and reaches a good development. Balsam fir attains its best growth and largest sizes on the flats, the soil of which is usually a moderately moist, deep, sand loam. In the wet swamps with acid soils, as well as on pure sand, it thrives but poorly.

SUSCEPTIBILITY TO DISEASE AND INJURY.

FUNGI.

Balsam fir must be classed as one of the most defective of our northeastern conifers. Its chief enemies are fungi, and the weakest point of attack is the heartwood.

According to its place of origin, the rot is known as top or ground rot, and is caused by two different species of fungi, *Trametes pini* and *Polyporus schweinitzii*.¹ The latter affects the merchantable portion of the tree, and therefore does the most injury. Even when the rot does not extend far up the trunk, the tree is nevertheless lost in lumbering, since the choppers, finding the butt rotten, will in many cases leave it partly cut through, to be broken down by the first wind. Thus is the whole tree wasted, although at a short distance from the ground it might be perfectly sound. The roots are the chief points of entrance for ground rot. Ground rot is especially common in balsam on slopes in mixture with hardwoods. Its relative infrequency in the swamps is most likely due to the excess of water and poor aeration in the soil, as well as the antiseptic effect of bog water. Ground rot may also find entrance through wounds on the lateral roots. Being near the surface and extending for several feet from the base of the tree, these are readily injured in logging by falling trees or by logs dragged over them. Roots may also be wounded by sharp rocks, or they may be broken by a strong wind, or insects may puncture them. In many cases ground rot was found to be associated with deep frost cracks and holes made by ants.

Top rot, affecting the upper and less merchantable part of the tree, is less common than ground rot. It was especially noted in suppressed trees, the tops of which are often injured by rubbing against other trees, though any kind of a wound in the top may afford an entrance to the fungus. Balsam fir beneath hardwoods is often suppressed for many years, and is therefore likely to be affected by rot in the top. The same is true of dense, pure stands, in which suppressed trees eventually die from the top.

Not many opportunities were afforded to study the rate at which the rot spreads, because it was impossible to tell when a frost crack or an insect wound was made. Only wounds made by falling trees, the axe, etc., could be used. The heartwood on the stump was, as a rule, completely rotten if the wound had been made low down upon the tree from five to seven years before. During that time the rot had extended upward for from 5 to 10 feet. The rate of spreading at the top was less rapid.

¹ Hedgcock, George G. Notes on Some Diseases of Trees in our National Forests, II. Phytopathology 2: 77-78, April, 1912.

Since the fruiting bodies of the fungi, or, as the lumbermen call them, "punks" or "conks," appear on the fir after the tree is considerably rotten, it is exceedingly hard to tell merely by the appearance of the tree whether it is sound or not. Being short-lived, balsam fir at the age of 80 to 100 years is already old, and especially susceptible to rot of any kind. Therefore one seldom finds an old balsam that is perfectly sound.

"GLASSY" FIR.

During the winter months balsam fir logs often have on cross section a "glassy" or "icy" appearance, which some lumbermen consider an indication of defect. When cut by the crosscut saw, the wood shows irregular areas which are perfectly smooth and shiny as if planed. A microscopical examination of the wood,¹ however, did not reveal any signs of decay in the smooth areas, and the structure could not be distinguished from that of the ordinary rough areas. During winter the water present in the wood of balsam fir is mostly frozen, and the shiny, smooth spots are therefore not due to any disease, but to the frozen condition of the wood. That this is so is further shown by the fact that the same section of wood when cut in an unfrozen condition appears rough over its entire area. The ice formed in the wood acts as reenforcing material and prevents the usual tearing of the wood fiber.

FIRE.

Balsam fir is very sensitive to fire. Its superficial roots are easily affected by surface fires, and the flames reach its cambium through the thin, tender bark, killing the tree. In a balsam injured by fire the lower foliage first turns brown, and finally the top. The dying in some cases is very slow, but is none the less certain.

WIND.

Balsam fir does not suffer from windshake, but it is easily uprooted and broken by wind because of its shallow root system and slender, brittle bole.

THE WOOD.

GENERAL STRUCTURE.

The wood of the balsam fir in external appearance is strikingly like that of eastern spruce, and it is often necessary to go to the gross and minute characters of its anatomical structure in order to distinguish it. Balsam fir is ordinarily close-grained and, like

¹ Glassy Fir, by Hermann von Schrenk. Sixteenth Annual Report of the Missouri Botanical Garden, pp. 117-120. St. Louis, Mo., 1905.

spruce, has no distinct heartwood and sapwood. Its narrow pith rays of a pale or whitish color are scarcely visible. Air-dry wood of balsam fir is light, weighing 24 pounds per cubic foot, as compared with 28 pounds for spruce. When completely dry, it has an average density of 0.38, and loses about 4 per cent of its volume in seasoning.

COMPARATIVE LENGTH OF WOOD FIBERS OF BALSAM FIR AND SPRUCES.

Table 7 gives the average, maximum, and minimum lengths of the wood fibers of balsam fir and the northeastern spruces.

TABLE 7.—Average, maximum, and minimum lengths of fibers of balsam fir and the northeastern spruces.

Species.	Length of wood fiber (millimeters).		
	Average.	Maximum.	Minimum.
Balsam fir (<i>Abies balsamea</i>).....	2.518	3.750	1.680
White spruce (<i>Picea canadensis</i>).....	3.556	4.704	2.520
Red spruce (<i>Picea rubens</i>).....	3.233	4.153	1.890
Black spruce (<i>Picea mariana</i>).....	2.599	3.738	2.142

GROWTH.

Balsam fir is a fairly rapid growing tree, though not as rapid as tamarack and white pine.

HEIGHT GROWTH.

Balsam fir has a period of comparatively slow growth, which, under favorable light conditions, lasts only for the first five years of its life; a period of rapid growth then sets in and continues until the tree is 60 years old. From then on the growth in height begins to decline, and at 80 years the growth is practically at a standstill. At 150 years it stops altogether. The most rapid growth in height takes place between the twentieth and fortieth years.

The slow growth of balsam fir for the first five or six years is an inherent characteristic of the species, and occurs even under the best light conditions. Beneath the shade of other trees, however, the period of slow growth is often extended to 25 years or more because of the retarding effect of the shade.

TABLE 8.—Comparative growth of balsam fir seedlings, in Franklin County, N. Y., in the shade¹ and in full light.²

Age (years).	Height of average trees under average conditions of shade.	Height of best trees under full light.	Age (years).	Height of average trees under average conditions of shade.	Height of best trees under full light.
	<i>Feet.</i>	<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>
1.....	0.1	0.1	10.....	1.6	3.6
2.....	.2	.2	11.....	1.9	4.3
3.....	.3	.4	12.....	2.1	5.1
4.....	.5	.7	13.....	2.4	5.8
5.....	.6	1.0	14.....	2.6	6.6
6.....	.7	1.5	15.....	2.8	7.4
7.....	.9	1.9	16.....	3.1	8.2
8.....	1.1	2.5	17.....	3.3	8.9
9.....	1.3	3.0	18.....	3.5	9.7

¹ Based on 324 trees.² Based on 104 trees.

Thus, with conditions of growth obtaining under forest management, the growth in height of balsam fir would be increased more than two and one-half times during the first 18 years of its life (9.7 feet as compared with 3.5 feet).

Tables 9 and 10 give the average growth in height on flat, swamp, and hardwood slope in the State of New York, based on age.

TABLE 9.—Height growth of balsam fir in New York, on the basis of age, on flat, swamp, and hardwood slope.

Age (years).	Flat. (Based on 248 trees.)			Swamp. (Based on 158 trees.)			Hardwood slope. (Based on 277 trees.)		
	Maxi- mum.	Mini- mum.	Average.	Maxi- mum.	Mini- mum.	Average.	Maxi- mum.	Mini- mum.	Average.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
10.....	8	3	5	10	3	4	8	3	5
15.....	13	7	9	15	6	7	15	6	9
20.....	18	11	14	19	8	11	22	9	14
25.....	24	15	19	24	10	15	28	13	19
30.....	29	19	23	28	12	19	34	17	24
35.....	34	22	27	32	14	23	40	21	30
40.....	39	25	31	36	16	27	45	25	35
45.....	44	27	35	39	18	30	50	29	39
50.....	49	29	38	42	20	32	54	32	43
55.....	52	30	41	45	21	34	58	35	47
60.....	56	32	43	48	23	36	61	38	49
65.....	59	33	45	51	24	38	64	40	52
70.....	61	34	47	53	25	40	66	42	54
75.....	63	35	49	55	26	41	68	43	56
80.....	65	36	51	57	27	43	69	45	57
85.....	67	37	52	59	28	44	70	45	58
90.....	68	38	53	60	29	46	71	46	59
95.....	69	39	54	62	30	47	72	47	60
100.....	70	39	55	63	30	48	73	47	61
105.....	71	40	56	64	31	49	73	48	61
110.....	72	41	57	65	32	50	74	48	62
115.....	72	42	58	66	32	51	74	49	62
120.....	73	42	59	67	33	52	75	49	63
125.....	74	43	59	68	34	52	75	49	63
130.....	74	44	60	69	34	53	75	50	63
135.....	74	45	60	70	35	53	76	50	63
140.....	75	46	61	70	35	54	76	50	63
145.....	75	46	62	71	36	54	76	51	64
150.....	75	47	62	72	37	55	76	51	64

TABLE 10.—Average growth of balsam fir in New York, on the basis of age, on flat, swamp, and hardwood slope.

Age (years).	Flat. (Based on 248 trees.)			Swamp. (Based on 158 trees.)			Hardwood slope. (Based on 277 trees.)		
	Height.	Growth in height every 5 years.	Annual growth in height within 5-year period.	Height.	Growth in height every 5 years.	Annual growth in height within 5-year period.	Height.	Growth in height every 5 years.	Annual growth in height within 5-year period.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
10.....	5			4			5		
15.....	9	4	0.8	7	3	0.6	9	4	0.8
20.....	14	5	1.0	11	4	.8	14	5	1.0
25.....	19	5	1.0	15	4	.8	19	5	1.0
30.....	23	4	.8	19	4	.8	24	5	1.0
35.....	27	4	.8	23	4	.8	30	6	1.2
40.....	31	4	.8	27	4	.8	35	5	1.0
45.....	35	4	.8	30	3	.6	39	4	.8
50.....	38	3	.6	32	2	.4	43	4	.8
55.....	41	3	.6	34	2	.4	47	4	.8
60.....	43	2	.4	36	2	.4	49	2	.4
65.....	45	2	.4	38	2	.4	52	3	.6
70.....	47	2	.4	40	2	.4	54	2	.4
75.....	49	2	.4	41	1	.2	56	2	.4
80.....	51	2	.4	43	2	.4	57	1	.2
85.....	52	1	.2	44	1	.2	58	1	.2
90.....	53	1	.2	46	2	.4	59	1	.2
95.....	54	1	.2	47	1	.2	60	1	.2
100.....	55	1	.2	48	1	.2	61	1	.2
105.....	56	1	.2	49	1	.2	61	0	.0
110.....	57	1	.2	50	1	.2	62	1	.2
115.....	58	1	.2	51	1	.2	62	0	.0
120.....	59	1	.2	52	1	.2	63	1	.2
125.....	59	0	.0	52	0	.0	63	0	.0
130.....	60	1	.2	53	1	.2	63	0	.0
135.....	60	0	.0	53	0	.0	63	0	.0
140.....	61	1	.2	54	1	.2	63	0	.0
145.....	62	1	.2	54	0	.0	64	1	.2
150.....	62	0	.0	55	1	.2	64	0	.0

In New York balsam fir grows in height at an average rate for all types of 0.4 of a foot a year.

On flats the growth between the ages of 20 and 45 is nearly 1 foot a year. At 60 years the current annual growth equals the average annual growth, namely 0.4 foot, which indicates that at this age the annual growth begins to decline. At the age of 85 the current annual growth is only 0.2 of a foot, and at 125 years has practically stopped.

In the swamp the growth in general is slower and on the hardwood slope faster than on the flat, but on the whole it culminates and begins to decline at about the same age in all three types.

In Maine (Table 11) the average tree grows faster than in New York; namely, at the rate of 0.7 of a foot a year. The period of most rapid growth is longer from the twentieth to the fiftieth year and the total height is greater.

TABLE 11.—*Height growth of balsam fir in Maine, on the basis of age, based on 456 trees.*

Age (years).	Height of tree (feet).			Annual growth within 5-year period (feet).	Age (years).	Height of tree (feet).			Annual growth within 5-year period (feet).
	Maxi-mum.	Mini-mum.	Aver-age.			Maxi-mum.	Mini-mum.	Aver-age.	
15.....	10	.....	8	0.5	60.....	69	21	52	0.7
20.....	22	6	14	1.2	65.....	72	24	56	.7
25.....	33	7	20	1.2	70.....	74	27	59	.6
30.....	42	8	25	1.0	75.....	76	31	61	.5
35.....	49	10	30	1.0	80.....	78	35	64	.5
40.....	55	12	36	1.0	85.....	79	38	66	.4
45.....	60	14	40	1.0	90.....	81	41	68	.4
50.....	63	16	45	1.0	95.....	82	45	70	.4
55.....	67	18	49	.8	100.....	83	48	71	.2

Table 12 shows the relation between the height and diameter growth for all types together in New York, Maine, New Hampshire, and Minnesota.

TABLE 12.—*Comparative height growth of balsam fir in different States, on the basis of diameter breast high.*

Diameter breast high (inches).	Height of tree (feet).			
	New York. ¹	Maine. ²	New Hampshire. ³	Minnesota. ⁴
1.....	9	12	15	8
2.....	17	20	24	16
3.....	26	27	31	23
4.....	33	35	37	31
5.....	40	42	42	37
6.....	46	48	46	43
7.....	51	54	50	48
8.....	54	60	53	53
9.....	58	64	56	58
10.....	60	68	59	62
11.....	63	72	61	67
12.....	65	75	63	.....
13.....	67	78	65	.....
14.....	70	81	67	.....
15.....	72	84	69	.....
16.....	74	86	70	.....
17.....	76	.....	72	.....

¹ All types, based on 1,138 trees.

² All types, based on 456 trees.

³ All types, based on 326 trees.

⁴ All types, based on 165 trees.

These figures indicate again that the tree reaches its best development in Maine and its next best in New York. Growth in Minnesota, though apparently more rapid than in New Hampshire or New York, on the whole is poorer than in any other State. The actual number of trees on which the figures for Minnesota are based is not large, while the figures for height growth in New Hampshire are based not on actual measurements of felled trees but on those of standing trees by means of a height measurer. If the measurements in the two States had been taken in the same way and on the same number of trees, the difference in favor of Minnesota would have been eliminated.

DIAMETER GROWTH.

Balsam fir makes its most rapid growth in diameter between the ages of 25 and 70 years, during which time the average rate is about 0.11 of an inch a year, or 1 inch in 9 years. On less favorable situations it grows at the rate of about 1 inch in 10 years. After the seventieth year the diameter growth begins to decline, and at 75 years the current annual growth falls below the mean annual growth.

Tables 13 and 14 give the growth of balsam fir in diameter on different stations in the Adirondacks.

TABLE 13.—*Diameter growth, in inches, of balsam fir in New York, on the basis of age.*

Age (years).	Hardwood slope. (Based on 277 trees.)			Flat. (Based on 246 trees.)			Swamp. (Based on 153 trees.)		
	Diam- eter breast high.	Growth in di- ameter every 5 years.	Annual growth in di- ameter within 5-year period.	Diam- eter breast high.	Growth in di- ameter every 5 years.	Annual growth in di- ameter within 5-year period.	Diam- eter breast high.	Growth in di- ameter every 5 years.	Annual growth in di- ameter within 5-year period.
10.....	0.4			0.4			0.3		
15.....	.8	0.4	0.08	.8	0.4	0.08	.6	0.3	0.06
20.....	1.3	.5	.10	1.2	.4	.08	1.0	.4	.08
25.....	1.9	.6	.12	1.7	.5	.10	1.4	.4	.08
30.....	2.6	.7	.14	2.3	.6	.12	1.8	.4	.08
35.....	3.3	.7	.14	2.9	.6	.12	2.3	.5	.10
40.....	4.0	.7	.14	3.6	.7	.14	2.8	.5	.10
45.....	4.7	.7	.14	4.3	.7	.14	3.3	.5	.10
50.....	5.4	.7	.14	4.9	.6	.12	3.8	.5	.10
55.....	6.0	.6	.12	5.5	.6	.12	4.4	.6	.12
60.....	6.5	.5	.10	6.0	.5	.10	4.9	.5	.10
65.....	7.0	.5	.10	6.5	.5	.10	5.4	.5	.10
70.....	7.4	.4	.08	6.9	.4	.08	5.8	.4	.08
75.....	7.8	.4	.08	7.2	.3	.06	6.1	.3	.06
80.....	8.2	.4	.08	7.5	.3	.06	6.5	.4	.08
85.....	8.5	.3	.06	7.8	.3	.06	6.8	.3	.06
90.....	8.9	.3	.06	8.1	.3	.06	7.1	.3	.06
95.....	9.2	.3	.06	8.3	.2	.04	7.4	.3	.06
100.....	9.5	.3	.06	8.6	.3	.06	7.6	.2	.04
105.....	9.8	.3	.06	8.9	.3	.06	7.9	.3	.06
110.....	10.1	.3	.06	9.1	.2	.04	8.1	.2	.04
115.....	10.4	.3	.06	9.4	.3	.06	8.4	.3	.06
120.....	10.7	.3	.06	9.6	.2	.04	8.6	.2	.04
125.....	11.0	.3	.06	9.9	.3	.06	8.8	.2	.04
130.....	11.3	.3	.06	10.1	.2	.04	9.1	.3	.06
135.....	11.6	.3	.06	10.3	.2	.04	9.3	.2	.04
140.....	11.9	.3	.06	10.5	.2	.04	9.5	.2	.04
145.....	12.2	.3	.06	10.8	.3	.06	9.8	.3	.06
150.....	12.5	.3	.06	11.0	.2	.04	10.0	.2	.04

TABLE 14.—*Number of years required by balsam fir in New York to grow 1 inch.*

Diameter breast high (inches).	Hardwood slope. (Based on 277 trees.)		Flat. (Based on 246 trees.)		Swamp. (Based on 153 trees.)	
	Age (years).	Years required to grow 1 inch.	Age (years).	Years required to grow 1 inch.	Age (years).	Years required to grow 1 inch.
1.....	17	17	18	18	20	20
2.....	26	9	28	10	32	12
3.....	33	7	36	8	42	10
4.....	40	7	43	7	52	10
5.....	47	7	51	8	61	9
6.....	55	8	60	9	73	12
7.....	65	10	72	12	89	16
8.....	78	13	89	17	108	19
9.....	93	15	108	19	129	21
10.....	108	15	128	20	150	21
11.....	125	17	150	22		
12.....	142	17				



TRANSVERSE SECTION OF THE STEM OF A YOUNG BALSAM FIR TREE, SHOWING ANNUAL RINGS OF GROWTH, *a. r.* NATURAL SIZE.

As shown by the tables, the best growth is made on hardwood slope; the poorest in swamps.

Table 15 shows the diameter growth of balsam fir in Maine for all types. The average growth here equals the best growth in the Adirondacks. On the whole, however, the periods of most rapid and slowest growth coincide.

TABLE 15.—*Diameter growth of balsam fir in Maine, on the basis of age. (All types, based on 456 trees.)*

Age (years).	Diameter breast high.	Growth in diameter every 5 years.	Annual growth in diameter within 5-year period.	Age (years).	Diameter breast high.	Growth in diameter every 5 years.	Annual growth in diameter within 5-year period.
	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.
15.....	0.4			85.....	9.4	0.5	0.10
20.....	1.2	0.8	0.16	90.....	9.9	.5	.10
25.....	2.0	.8	.16	95.....	10.4	.5	.10
30.....	2.7	.7	.14	100.....	10.7	.3	.06
35.....	3.4	.7	.14	105.....	11.0	.3	.06
40.....	4.1	.7	.14	110.....	11.3	.3	.06
45.....	4.8	.7	.14	115.....	11.6	.3	.06
50.....	5.5	.7	.14	120.....	11.9	.3	.06
55.....	6.1	.6	.12	125.....	12.1	.2	.04
60.....	6.7	.6	.12	130.....	12.3	.2	.04
65.....	7.3	.6	.12	135.....	12.5	.2	.04
70.....	7.9	.6	.12	140.....	12.6	.1	.02
75.....	8.4	.5	.10	145.....	12.8	.2	.04
80.....	8.9	.5	.10	150.....	12.9	.1	.02

SUMMARY.

Diameter breast high (inches).	Age (years).	Years required to grow 1 inch.	Diameter breast high (inches).	Age (years).	Years required to grow 1 inch.
1.....	19	19	8.....	71	9
2.....	25	6	9.....	81	10
3.....	32	7	10.....	91	10
4.....	39	7	11.....	105	14
5.....	47	8	12.....	123	18
6.....	54	7	13.....	152	29
7.....	62	8			

EFFECT OF OPENING UP FOREST UPON DIAMETER GROWTH.

That the diameter growth of balsam fir is stimulated by opening up the forest is indicated by measurements of trees growing on uncut and on culled land (Table 16).

TABLE 16.—*Diameter growth of balsam fir, Grafton County, N. H., on uncut and culled land.*

Present diameter breast high (inches).	Diameter, in inches, breast high after 10 years.		Present diameter breast high (inches).	Diameter, in inches, breast high after 10 years.	
	Uncut land.	Culled land.		Uncut land.	Culled land.
6.....	6.54	6.80	10.....	11.18	11.40
7.....		7.80	11.....	11.88	12.34
8.....	9.26	9.56	12.....	12.88	13.34
9.....	10.20	10.60	13.....		14.34

COMPARATIVE GROWTH OF SPRUCE AND BALSAM FIR.

Since spruce and balsam fir nearly always grow together, and any plan of management for one species must necessarily include the other, a comparison of the growth of the two species is essential.

In Table 17 is contrasted the average growth in height and diameter of balsam fir and spruce in the State of Maine.

TABLE 17.—*Comparative growth, in height and diameter, of balsam fir and red spruce in Maine.*

GROWTH IN HEIGHT.

Diameter breast high (inches).	Height (feet).		Diameter breast high (inches).	Height (feet).	
	Red spruce. (Based on 485 trees.)	Balsam fir. (Based on 456 trees.)		Red spruce. (Based on 485 trees.)	Balsam fir. (Based on 456 trees.)
1.....	7	12	10.....	52	68
2.....	14	20	11.....	55	72
3.....	21	27	12.....	58	75
4.....	28	35	13.....	60	78
5.....	33	42	14.....	63	81
6.....	37	48	15.....	65	84
7.....	41	54	16.....	67	86
8.....	44	60	17.....	68	.....
9.....	48	64	18.....	70	.....

GROWTH IN DIAMETER.

Age (years).	Diameter breast high (inches).		Age (years).	Diameter breast high (inches).	
	Red spruce. (Based on 274 trees.)	Balsam fir. (Based on 456 trees.)		Red spruce. (Based on 274 trees.)	Balsam fir. (Based on 456 trees.)
20.....	0.1	1.2	90.....	2.7	9.9
30.....	.6	2.7	100.....	3.2	10.7
40.....	.8	4.1	110.....	3.7	11.3
50.....	1.1	5.5	120.....	4.3	11.9
60.....	1.5	6.7	130.....	4.9	12.3
70.....	1.8	7.9	140.....	5.5	12.6
80.....	2.2	8.9	150.....	6.2	12.9

Red spruce grows in height much slower than balsam fir for the first 70 years. At a diameter of about 8 inches its rate of growth in height is approximately the same as that of balsam fir. At a diameter of 12 inches balsam fir reaches almost its full height, while spruce is still far below its fullest development. From that time on spruce continues to grow at a uniform rate for a long period, while the growth of balsam fir is rapidly declining until at a diameter of about 16 inches it practically ceases.

The same is true of the growth in diameter. At the age of 100 years spruce is only 3.2 inches in diameter breast high, while balsam fir has made nearly two-thirds of its entire diameter growth. After

the age of 70 years the annual growth of balsam fir declines, while that of spruce shows a gradual increase. After the age of 150 years spruce catches up with balsam fir, and finally surpasses it both in height and diameter. On the whole the rate of growth of balsam fir is more rapid during its entire life than that of spruce. The growth of spruce is, however, more persistent, and does not exhaust itself as early. It is this persistent growth and its long life which enable spruce to reach larger dimensions.

This difference in growth is also apparent on cut-over land. Measurements in New Hampshire during 10 years following cutting gave the results shown in Table 18.

TABLE 18.—*Comparative growth in diameter of spruce and balsam on culled land in Grafton County, N. H.*

Diameter breast high at time of cutting (inches).	Diameter breast high after 10 years (inches).		Diameter breast high at time of cutting (inches).	Diameter breast high after 10 years (inches).	
	Spruce.	Balsam.		Spruce.	Balsam.
8.....	8.82	9.56	14.....	14.64	.....
9.....	10.00	10.60	15.....	15.64	.....
10.....	11.00	11.40	16.....	16.64	.....
11.....	12.00	12.34	17.....	17.64	.....
12.....	13.00	13.34	18.....	18.64	.....
13.....	14.00	14.34			

Balsam fir up to 13 inches in diameter responded to increased light and space more vigorously than spruce, but did not go beyond the limit of 14 inches, while spruce continued to show a slower but a uniform increase in growth of 1 inch for each 1 inch in diameter up to 18 inches.

VOLUME GROWTH.

Tables 19 to 23 give the increment of balsam fir in cubic feet and board measure for the three different types in New York and in cubic feet for all types in Maine. The tables of volume growth, more than the tables of height and diameter growth, bring out the better development of balsam fir in Maine than in New York and other States. The annual increment in Maine is practically twice that in New York. Similarly, the volume-growth tables bring out more clearly the differences in the increment of balsam fir in different situations. Thus, in the swamp the increment is less than in the flat or on the hardwood slope but is more persistent, illustrated by the fact that at the age of 150 years it still continues at an increasing rate. In the swamp the growth of balsam fir resembles more nearly that of spruce. On the hardwood slope the volume growth of balsam fir shows the same tendency as that in height and diameter. It reaches its climax comparatively early and is greatest between the ages of 80 and 95 years. After

that it begins to decline. On the flat the maximum rate of volume growth is reached at an age between 50 and 85 years, after which it slightly declines and remains stationary until a very old age.

The increment in cubic feet becomes noticeable much later than the growth in height or diameter; namely, when the tree is 40 or 50 years old. This is still more marked in the case of the increment in board feet. Thus, up to 70 years, even on the hardwood slope, where the growth is fastest, no increment in board feet is noticeable. It reaches its highest rate at the age of 125 years, and continues at a fairly steady rate practically to the limit of the physical life of the tree. On the flat the increment in board feet starts at about 80 and in the swamp at from 90 to 95 years.

TABLE 19.—*Total volume, in cubic feet, of balsam fir in New York, on the basis of diameter and height.*

Diameter breast high (inches).	Height of tree (feet).						
	20	30	40	50	60	70	80
	Total volume (cubic feet).						
3.....	0.54	0.81					
4.....	.96	1.43	1.91				
5.....	1.48	2.21	2.95	3.60			
6.....		3.15	4.19	5.23	6.24	7.24	
7.....		4.24	5.63	7.01	8.37	9.72	11.07
8.....			7.25	9.01	10.76	12.51	14.24
9.....				11.19	13.38	15.55	17.71
10.....				13.59	16.23	18.86	21.47
11.....				16.10	19.25	22.36	25.50
12.....					22.38	26.06	29.72
13.....					25.71	29.94	34.14
14.....					29.12	33.98	38.74
15.....					32.77	38.14	43.59
16.....					36.53	42.52	48.59

TABLE 20.—*Total volume, in cubic feet, of balsam fir in Maine, on the basis of diameter and height.*

Diameter breast high (inches).	Height of tree (feet).				
	40	50	60	70	80
	Total volume (cubic feet).				
7.....	5.68	7.20	8.76	10.34	.....
8.....	7.22	9.17	11.12	13.22	15.33
9.....	8.87	11.26	13.75	16.33	18.98
10.....		13.20	16.49	19.66	22.91
11.....		15.77	19.40	23.15	27.03
12.....			22.38	26.83	31.42
13.....			25.44	30.58	35.91
14.....			28.48	34.35	40.45
15.....			31.52	38.14	45.06
16.....			34.52	42.03	49.71

TABLE 21.— *Volume growth, in board feet, of balsam fir in New York, on the basis of age.*

Age (years).	Hardwood slope.			Flat.			Swamp.		
	Vol- ume.	Growth in vol- ume every 5 years.	Annual growth in vol- ume within 5-year period.	Vol- ume.	Growth in vol- ume every 5 years.	Annual growth in vol- ume within 5-year period.	Vol- ume.	Growth in vol- ume every 5 years.	Annual growth in vol- ume within 5-year period.
65.....	22								
70.....	25	3	0.6						
75.....	28	3	.6	20					
80.....	32	4	.8	23	3	0.6			
85.....	35	3	.6	26	3	.6			
90.....	39	4	.8	29	3	.6	16		
95.....	43	4	.8	32	3	.6	18	2	0.4
100.....	47	4	.8	34	2	.4	20	2	.4
105.....	51	4	.8	37	3	.6	22	2	.4
110.....	55	4	.8	40	3	.6	24	2	.4
115.....	59	4	.8	43	3	.6	26	2	.4
120.....	63	4	.8	46	3	.6	28	2	.4
125.....	68	5	1.0	50	4	.8	31	3	.6
130.....	73	5	1.0	53	3	.6	33	2	.4
135.....	78	5	1.0	56	3	.6	36	3	.6
140.....	83	5	1.0	60	4	.8	33	2	.4
145.....	87	4	.8	63	3	.6	41	3	.6
150.....	92	5	1.0	66	3	.6	43	2	.4

TABLE 22.— *Volume growth, in cubic feet, of balsam fir in New York, on the basis of age.*

Age (years).	Hardwood slope.			Flat.			Swamp.		
	Vol- ume.	Growth in vol- ume every 5 years.	Annual growth in vol- ume within 5-year period.	Vol- ume.	Growth in vol- ume every 5 years.	Annual growth in vol- ume within 5-year period.	Vol- ume.	Growth in vol- ume every 5 years.	Annual growth in vol- ume within 5-year period.
40.....	1.73	1.09	0.218	1.09					
45.....	2.82	1.09	.218	1.92	0.83	0.166	0.98		
50.....	3.91	1.09	.218	2.80	.88	.176	1.47	0.49	0.098
55.....	5.00	1.09	.218	3.67	.87	.174	2.01	.54	.108
60.....	6.10	1.10	.220	4.57	.90	.180	2.60	.59	.118
65.....	7.20	1.10	.220	5.47	.90	.180	3.21	.61	.122
70.....	8.30	1.10	.220	6.36	.89	.178	3.88	.67	.134
75.....	9.40	1.10	.220	7.23	.87	.174	4.56	.68	.136
80.....	10.50	1.10	.220	8.09	.86	.172	5.24	.68	.136
85.....	11.63	1.13	.226	8.91	.82	.164	5.92	.68	.136
90.....	12.74	1.11	.222	9.74	.83	.166	6.59	.67	.134
95.....	13.85	1.11	.222	10.56	.82	.164	7.26	.67	.134
100.....	14.93	1.08	.216	11.40	.84	.168	7.94	.68	.136
105.....	16.00	1.07	.214	12.23	.83	.166	8.62	.68	.136
110.....	17.05	1.05	.210	13.09	.86	.172	9.30	.68	.136
115.....	18.10	1.05	.210	13.94	.85	.170	9.98	.68	.136
120.....	19.15	1.05	.210	14.80	.86	.172	10.66	.68	.136
125.....	20.19	1.04	.208	15.64	.84	.168	11.34	.68	.136
130.....	21.23	1.04	.208	16.50	.86	.172	12.02	.68	.136
135.....	22.29	1.06	.212	17.34	.84	.168	12.70	.68	.136
140.....	23.34	1.05	.210	18.20	.86	.172	13.38	.68	.136
145.....	24.37	1.03	.206	19.04	.84	.168	14.09	.71	.142
150.....	25.43	1.06	.212	19.90	.86	.172	14.80	.71	.142

TABLE 23.—*Volume growth, in cubic feet, of balsam fir in Maine, on the basis of age.*

Age (years).	Volume.	Growth in volume every 5 years.	Annual growth in volume within 5-year period.
65.....	8.81		
70.....	10.64	1.83	0.366
75.....	12.55	1.91	.382
80.....	14.50	1.95	.390
85.....	16.51	2.01	.402
90.....	18.60	2.09	.418
95.....	20.73	2.13	.426
100.....	22.90	2.17	.434

TAPER.

Tables 24 to 29 show the taper of balsam fir in different situations in New York and Maine, expressed in inches and in per cent of the diameter breast high. The diameter breast high inside bark is taken as 100, and the diameters inside bark at 10, 20, 30, etc., feet from the ground expressed as fractions.

These taper tables furnish a basis for the construction of volume tables in any log scale or in cubic measure, and serve in general to indicate the development of the bole under various conditions of growth. Thus, they show the more spindling development of balsam fir in the swamp than on either the flat or hardwood slope, and the better development, on the whole, in Maine than in New York.

TABLE 24.—*Taper of balsam fir in New York on swamp.*

[Expressed in per cent of the diameter inside bark breast high.]

Diameter breast high (inches).	Height above ground (feet).						
	4.5	10	20	30	40	50	60
20-foot trees.							
2.....	100	72.2					
3.....	100	74.1					
4.....	100	70.3					
30-foot trees.							
2.....	100	84.2	52.6				
3.....	100	85.7	57.1				
4.....	100	86.5	56.8				
5.....	100	89.1	58.7				
6.....	100	87.5	58.9				
7.....	100	89.2	60.0				
40-foot trees.							
2.....	100	89.5	68.4	42.1			
3.....	100	89.3	71.4	42.9			
4.....	100	91.9	73.0	43.2			
5.....	100	91.5	72.3	44.7			
6.....	100	91.1	73.2	46.4			
7.....	100	92.3	75.4	46.2			
8.....	100	92.0	74.7	46.7			
9.....	100	91.8	72.9	47.1			

TABLE 24.—*Taper of balsam fir in New York on swamp—Continued.*

Diameter breast high (inches).	Height above ground (feet).						
	4.5	10	20	30	40	50	60
50-foot trees.							
4.....	100	92.1	78.9	63.2	28.9	.....	.....
5.....	100	93.6	80.9	61.7	31.9	.....	.....
6.....	100	93.0	77.2	59.6	31.6	.....	.....
7.....	100	93.9	78.8	59.1	31.8	.....	.....
8.....	100	93.3	78.7	58.7	33.3	.....	.....
9.....	100	91.8	77.6	57.6	32.9	.....	.....
10.....	100	91.5	77.7	57.4	33.0	.....	.....
11.....	100	92.2	77.7	57.3	33.0	.....	.....
12.....	100	91.2	77.0	56.6	31.9	.....	.....
13.....	100	91.0	76.2	56.6	32.0	.....	.....
60-foot trees.							
6.....	100	94.7	82.5	66.7	47.4	24.6	.....
7.....	100	93.9	81.8	66.7	47.0	24.2	.....
8.....	100	93.4	81.6	65.8	46.1	23.7	.....
9.....	100	92.9	81.2	65.9	45.9	23.5	.....
10.....	100	93.6	80.9	66.0	45.7	23.4	.....
11.....	100	92.3	80.8	65.4	46.2	23.1	.....
12.....	100	92.0	80.5	65.5	46.0	23.9	.....
13.....	100	91.1	79.7	65.9	46.3	23.6	.....
70-foot trees.							
6.....	100	94.8	82.8	67.2	50.0	31.0	13.8
7.....	100	94.0	83.6	68.7	52.2	32.8	16.4
8.....	100	94.7	82.9	69.7	52.6	35.5	17.1
9.....	100	94.1	83.5	70.6	55.3	36.5	17.6
10.....	100	93.7	83.2	70.5	54.7	37.9	18.9
11.....	100	93.3	82.7	71.2	55.8	38.5	20.2
12.....	100	93.0	82.5	71.1	56.1	38.6	20.2
13.....	100	91.9	82.3	71.0	56.5	39.5	21.0

TABLE 25.—*Diameter inside bark, in inches, of balsam fir in New York on swamp, at different heights above the ground.*

[Based on 341 trees.]

Diameter breast high (inches).	Height above ground (feet).						
	4.5	10	20	30	40	50	60
Diameter inside bark (inches).							
20-foot trees.							
2.....	1.8	1.3	.....	.....	.....	.....	.....
3.....	2.7	2.0	.....	.....	.....	.....	.....
4.....	3.7	2.6	.....	.....	.....	.....	.....
30-foot trees.							
2.....	1.9	1.6	1.0	.....	.....	.....	.....
3.....	2.8	2.4	1.6	.....	.....	.....	.....
4.....	3.7	3.2	2.1	.....	.....	.....	.....
5.....	4.6	4.1	2.7	.....	.....	.....	.....
6.....	5.6	4.9	3.3	.....	.....	.....	.....
7.....	6.5	5.8	3.9	.....	.....	.....	.....

TABLE 25.—*Diameter inside bark, in inches, of balsam fir in New York on swamp, at different heights above the ground—Continued.*

	Height above ground (feet).						
Diameter breast high (inches).	4.5	10	20	30	40	50	60
	Diameter inside bark (inches).						
40-foot trees.							
2.....	1.9	1.7	1.3	0.8	.....	.....	.....
3.....	2.8	2.5	2.0	1.2	.....	.....	.....
4.....	3.7	3.4	2.7	1.6	.....	.....	.....
5.....	4.7	4.3	3.4	2.1	.....	.....	.....
6.....	5.6	5.1	4.1	2.6	.....	.....	.....
7.....	6.5	6.0	4.9	3.0	.....	.....	.....
8.....	7.5	6.9	5.6	3.5	.....	.....	.....
9.....	8.5	7.8	6.2	4.0	.....	.....	.....
50-foot trees.							
4.....	3.8	3.5	3.0	2.4	1.1	.....	.....
5.....	4.7	4.4	3.8	2.9	1.5	.....	.....
6.....	5.7	5.3	4.4	3.4	1.8	.....	.....
7.....	6.6	6.2	5.2	3.9	2.1	.....	.....
8.....	7.5	7.0	5.9	4.4	2.5	.....	.....
9.....	8.5	7.8	6.6	4.9	2.8	.....	.....
10.....	9.4	8.6	7.3	5.4	3.1	.....	.....
11.....	10.3	9.5	8.0	5.9	3.4	.....	.....
12.....	11.3	10.3	8.7	6.4	3.6	.....	.....
13.....	12.2	11.1	9.3	6.9	3.9	.....	.....
60-foot trees.							
6.....	5.7	5.4	4.7	3.8	2.7	1.4	.....
7.....	6.6	6.2	5.4	4.4	3.1	1.6	.....
8.....	7.6	7.1	6.2	5.0	3.5	1.8	.....
9.....	8.5	7.9	6.9	5.6	3.9	2.0	.....
10.....	9.4	8.8	7.6	6.2	4.3	2.2	.....
11.....	10.4	9.6	8.4	6.8	4.8	2.4	.....
12.....	11.3	10.4	9.1	7.4	5.2	2.7	.....
13.....	12.3	11.2	9.8	8.1	5.7	2.9	.....
70-foot trees.							
6.....	5.8	5.5	4.8	3.9	2.9	1.8	0.8
7.....	6.7	6.3	5.6	4.6	3.5	2.2	1.1
8.....	7.6	7.2	6.3	5.3	4.0	2.7	1.3
9.....	8.5	8.0	7.1	6.0	4.7	3.1	1.5
10.....	9.5	8.9	7.9	6.7	5.2	3.6	1.8
11.....	10.4	9.7	8.6	7.4	5.8	4.0	2.1
12.....	11.4	10.6	9.4	8.1	6.4	4.4	2.3
13.....	12.4	11.4	10.2	8.8	7.0	4.9	2.6

TABLE 26.—*Taper of balsam fir in New York on hardwood slope and flat.*

[Expressed in per cent of the diameter inside bark breast high.]

Diameter breast high (inches).	Height above ground (feet).							
	4.5	10	20	30	40	50	60	70
20-foot trees.								
2.....	100	77.8						
3.....	100	78.6						
4.....	100	78.4						
5.....	100	78.3						

TABLE 26.—*Taper of balsam fir in New York on hardwood slope and flat--Continued.*

Diameter breast high (inches).	Height above ground (feet).							
	4.5	10	20	30	40	50	60	70
30-foot trees.								
2.....	100	84.2	47.4	-----	-----	-----	-----	-----
3.....	100	89.3	53.6	-----	-----	-----	-----	-----
4.....	100	89.5	60.5	-----	-----	-----	-----	-----
5.....	100	91.5	63.3	-----	-----	-----	-----	-----
6.....	100	91.2	64.9	-----	-----	-----	-----	-----
7.....	100	92.4	68.2	-----	-----	-----	-----	-----
40-foot trees.								
2.....	100	94.7	73.7	47.4	-----	-----	-----	-----
3.....	100	92.9	75.0	50.0	-----	-----	-----	-----
4.....	100	92.1	73.7	50.0	-----	-----	-----	-----
5.....	100	91.7	75.0	50.0	-----	-----	-----	-----
6.....	100	93.0	75.4	50.9	-----	-----	-----	-----
7.....	100	91.0	74.6	50.7	-----	-----	-----	-----
8.....	100	92.1	76.3	52.6	-----	-----	-----	-----
9.....	100	91.9	75.6	52.3	-----	-----	-----	-----
10.....	100	91.6	76.8	53.7	-----	-----	-----	-----
50-foot trees.								
5.....	100	93.9	81.6	65.3	38.8	-----	-----	-----
6.....	100	93.1	81.0	63.8	37.9	-----	-----	-----
7.....	100	94.0	80.6	64.2	37.3	-----	-----	-----
8.....	100	93.4	81.6	64.5	36.8	-----	-----	-----
9.....	100	91.9	80.2	62.8	36.0	-----	-----	-----
10.....	100	92.6	80.0	63.2	36.8	-----	-----	-----
11.....	100	92.3	79.8	63.5	36.5	-----	-----	-----
12.....	100	92.1	78.9	63.2	36.8	-----	-----	-----
13.....	100	91.9	79.7	62.6	36.6	-----	-----	-----
60-foot trees.								
6.....	100	94.8	86.2	72.4	53.4	29.3	-----	-----
7.....	100	95.5	86.6	71.6	53.7	28.4	-----	-----
8.....	100	93.5	83.1	70.1	51.9	27.3	-----	-----
9.....	100	94.2	83.7	69.8	51.2	26.7	-----	-----
10.....	100	93.7	83.2	69.5	50.5	26.3	-----	-----
11.....	100	93.3	81.9	69.5	50.5	25.7	-----	-----
12.....	100	93.0	81.6	69.3	50.0	26.3	-----	-----
13.....	100	92.7	82.1	69.1	49.6	26.0	-----	-----
14.....	100	91.7	81.2	68.4	48.9	25.6	-----	-----
15.....	100	91.5	81.7	68.3	48.6	26.1	-----	-----
16.....	100	91.4	81.5	68.2	49.0	25.8	-----	-----
70-foot trees.								
8.....	100	94.8	87.0	75.3	61.0	42.9	23.4	-----
9.....	100	95.3	86.0	75.6	60.5	43.0	22.1	-----
10.....	100	94.7	85.3	74.7	60.0	42.1	22.1	-----
11.....	100	93.3	83.8	74.3	59.0	41.0	21.0	-----
12.....	100	93.9	84.2	73.7	58.8	40.4	21.1	-----
13.....	100	92.7	83.1	73.4	58.9	40.3	21.0	-----
14.....	100	92.5	82.7	72.9	58.6	39.8	21.1	-----
15.....	100	92.3	82.5	72.7	58.0	39.9	20.3	-----
16.....	100	92.1	82.9	73.0	57.9	40.1	20.4	-----
80-foot trees.								
9.....	100	95.3	88.4	80.2	67.4	52.3	34.9	16.3
10.....	100	94.7	87.4	78.9	66.3	51.6	34.7	16.8
11.....	100	94.2	86.5	77.9	66.3	51.0	34.6	17.3
12.....	100	93.9	85.1	76.3	64.9	50.9	34.2	17.5
13.....	100	93.5	84.7	75.8	64.5	50.0	34.7	17.7
14.....	100	93.3	83.6	75.4	63.4	50.0	34.3	17.9
15.....	100	93.0	83.9	74.8	63.6	50.3	35.0	18.2
16.....	100	92.8	83.0	74.5	63.4	49.7	35.3	18.3

TABLE 27.—*Diameter inside bark, in inches, of balsam fir in New York on hardwood slope and flat, at different heights above the ground.*

[Based on 1,109 trees.]

Diameter breast high (inches).	Height above ground (feet).							
	4.5	10	20	30	40	50	60	70
	Diameter inside bark (inches).							
20-foot trees.								
2.....	1.8	1.4	-----	-----	-----	-----	-----	-----
3.....	2.8	2.2	-----	-----	-----	-----	-----	-----
4.....	3.7	2.9	-----	-----	-----	-----	-----	-----
5.....	4.6	3.6	-----	-----	-----	-----	-----	-----
30-foot trees.								
2.....	1.9	1.6	0.9	-----	-----	-----	-----	-----
3.....	2.8	2.5	1.5	-----	-----	-----	-----	-----
4.....	3.8	3.4	2.3	-----	-----	-----	-----	-----
5.....	4.7	4.3	3.0	-----	-----	-----	-----	-----
6.....	5.7	5.2	3.7	-----	-----	-----	-----	-----
7.....	6.6	6.1	4.5	-----	-----	-----	-----	-----
40-foot trees.								
2.....	1.9	1.8	1.4	0.9	-----	-----	-----	-----
3.....	2.8	2.6	2.1	1.4	-----	-----	-----	-----
4.....	3.8	3.5	2.8	1.9	-----	-----	-----	-----
5.....	4.8	4.4	3.6	2.4	-----	-----	-----	-----
6.....	5.7	5.3	4.3	2.9	-----	-----	-----	-----
7.....	6.7	6.1	5.0	3.4	-----	-----	-----	-----
8.....	7.6	7.0	5.8	4.0	-----	-----	-----	-----
9.....	8.6	7.9	6.5	4.5	-----	-----	-----	-----
10.....	9.5	8.7	7.3	5.1	-----	-----	-----	-----
50-foot trees.								
5.....	4.9	4.6	4.0	3.2	1.9	-----	-----	-----
6.....	5.8	5.4	4.7	3.7	2.2	-----	-----	-----
7.....	6.7	6.3	5.4	4.3	2.5	-----	-----	-----
8.....	7.6	7.1	6.2	4.9	2.8	-----	-----	-----
9.....	8.6	7.9	6.9	5.4	3.1	-----	-----	-----
10.....	9.5	8.8	7.6	6.0	3.5	-----	-----	-----
11.....	10.4	9.6	8.3	6.6	3.8	-----	-----	-----
12.....	11.4	10.5	9.0	7.2	4.2	-----	-----	-----
13.....	12.3	11.3	9.8	7.7	4.5	-----	-----	-----
60-foot trees.								
6.....	5.8	5.5	5.0	4.2	3.1	1.7	-----	-----
7.....	6.7	6.4	5.8	4.8	3.6	1.9	-----	-----
8.....	7.7	7.2	6.4	5.4	4.0	2.1	-----	-----
9.....	8.6	8.1	7.2	6.0	4.4	2.3	-----	-----
10.....	9.5	8.9	7.9	6.6	4.8	2.5	-----	-----
11.....	10.5	9.8	8.6	7.3	5.3	2.7	-----	-----
12.....	11.4	10.6	9.3	7.9	5.7	3.0	-----	-----
13.....	12.3	11.4	10.1	8.5	6.1	3.2	-----	-----
14.....	13.3	12.2	10.8	9.1	6.5	3.4	-----	-----
15.....	14.2	13.0	11.6	9.7	6.9	3.7	-----	-----
16.....	15.1	13.8	12.3	10.3	7.4	3.9	-----	-----

TABLE 27.—*Diameter inside bark, in inches, of balsam fir in New York on hardwood slope and flat, at different heights above the ground—Continued.*

Diameter breast high (inches).	Height above ground (feet).							
	4.5	10	20	30	40	50	60	70
Diameter inside bark (inches).								
70-foot trees.								
8.....	7.7	7.3	6.7	5.8	4.7	3.3	1.8	.....
9.....	8.6	8.2	7.4	6.5	5.2	3.7	1.9	.....
10.....	9.5	9.0	8.1	7.1	5.7	4.0	2.1	.....
11.....	10.5	9.8	8.8	7.8	6.2	4.3	2.2	.....
12.....	11.4	10.7	9.6	8.4	6.7	4.6	2.4	.....
13.....	12.4	11.5	10.3	9.1	7.3	5.0	2.6	.....
14.....	13.3	12.3	11.0	9.7	7.8	5.3	2.8	.....
15.....	14.3	13.2	11.8	10.4	8.3	5.7	2.9	.....
16.....	15.2	14.0	12.6	11.1	8.8	6.1	3.1	.....
80-foot trees.								
9.....	8.6	8.2	7.6	6.9	5.8	4.5	3.0	1.4
10.....	9.5	9.0	8.3	7.5	6.3	4.9	3.3	1.6
11.....	10.4	9.8	9.0	8.1	6.9	5.3	3.6	1.8
12.....	11.4	10.7	9.7	8.7	7.4	5.8	3.9	2.0
13.....	12.4	11.6	10.5	9.4	8.0	6.2	4.3	2.2
14.....	13.4	12.5	11.2	10.1	8.5	6.7	4.6	2.4
15.....	14.3	13.3	12.0	10.7	9.1	7.2	5.0	2.6
16.....	15.3	14.2	12.7	11.4	9.7	7.6	5.4	2.8

TABLE 28.—*Taper of balsam fir in Maine.*

[Expressed in per cent of the diameter inside bark breast high.]

Diameter breast high (inches).	Height above ground (feet).								
	4.5	10	20	30	40	50	60	70	80
40-foot trees.									
6.....	100	94.7	80.7	50.9	.....	.....	.....	.....	.....
7.....	100	91.0	77.6	50.7	.....	.....	.....	.....	.....
8.....	100	90.8	76.3	50.0	.....	.....	.....	.....	.....
9.....	100	90.6	76.5	49.4	.....	.....	.....	.....	.....
10.....	100	89.5	74.7	49.5	.....	.....	.....	.....	.....
50-foot trees.									
6.....	100	94.7	82.5	64.9	36.8	.....	.....	.....	.....
7.....	100	92.5	80.6	64.2	35.8	.....	.....	.....	.....
8.....	100	92.1	80.3	64.5	36.8	.....	.....	.....	.....
9.....	100	91.8	81.2	63.5	37.6	.....	.....	.....	.....
10.....	100	91.6	80.0	64.2	37.9	.....	.....	.....	.....
11.....	100	91.3	79.8	63.5	39.4	.....	.....	.....	.....
12.....	100	92.0	80.5	63.7	39.8	.....	.....	.....	.....
60-foot trees.									
6.....	100	94.8	86.2	75.9	56.9	32.8	.....	.....	.....
7.....	100	94.0	85.1	74.6	56.7	32.8	.....	.....	.....
8.....	100	94.7	85.5	73.7	55.3	31.6	.....	.....	.....
9.....	100	93.0	83.7	72.1	54.7	31.4	.....	.....	.....
10.....	100	92.6	83.2	71.6	54.7	30.5	.....	.....	.....
11.....	100	93.3	82.7	71.2	53.8	30.8	.....	.....	.....
12.....	100	92.1	81.6	69.3	52.6	29.8	.....	.....	.....
13.....	100	91.9	80.5	68.3	52.0	29.3	.....	.....	.....
14.....	100	91.7	79.5	67.4	52.3	29.5	.....	.....	.....

TABLE 28.—*Taper of balsam fir in Maine—Continued.*

Diameter breast high (inches).	Height above ground (feet).								
	4.5	10	20	30	40	50	60	70	80
70-foot trees.									
8.....	100	96.1	89.5	80.3	68.4	48.7	27.6	.....	.....
9.....	100	94.2	87.2	77.9	65.1	47.7	26.7	.....	.....
10.....	100	94.7	86.3	76.8	64.2	47.4	26.3	.....	.....
11.....	100	93.3	84.8	75.2	62.9	46.7	24.8	.....	.....
12.....	100	93.0	84.2	74.6	62.3	45.6	24.6	.....	.....
13.....	100	92.7	83.7	74.0	61.8	44.7	23.6	.....	.....
14.....	100	92.5	82.7	72.9	60.9	43.6	23.3	.....	.....
15.....	100	92.3	81.7	71.8	59.9	43.0	22.5	.....	.....
16.....	100	92.1	80.8	70.9	59.6	42.4	21.9	.....	.....
80-foot trees.									
8.....	100	97.4	92.1	84.2	72.4	57.9	40.8	18.4	.....
9.....	100	95.3	89.5	82.6	70.9	57.0	39.5	18.6	.....
10.....	100	94.7	88.4	81.1	69.5	56.8	38.9	18.9	.....
11.....	100	94.3	86.7	79.0	68.6	55.2	38.1	18.1	.....
12.....	100	93.0	86.1	78.3	67.8	54.8	37.4	18.3	.....
13.....	100	93.5	85.5	77.4	67.7	54.8	37.1	18.5	.....
14.....	100	93.2	85.7	77.4	68.4	54.1	36.8	18.8	.....
15.....	100	93.0	84.6	76.9	67.8	53.8	37.1	18.9	.....
16.....	100	92.8	84.2	77.0	67.8	53.9	36.8	19.1	.....
90-foot trees.									
10.....	100	94.8	88.5	80.2	69.8	58.3	42.7	26.0	11.5
11.....	100	95.2	88.6	81.0	71.4	59.0	43.8	27.6	12.4
12.....	100	94.7	88.6	80.7	72.8	60.5	45.6	28.9	13.2
13.....	100	94.4	87.9	80.6	72.6	61.3	46.0	29.8	13.7
14.....	100	94.0	87.3	80.6	73.1	61.9	47.0	29.9	14.9
15.....	100	93.8	86.8	80.6	73.6	62.5	47.9	30.6	14.6
16.....	100	93.4	86.9	81.0	74.5	63.4	49.0	32.0	15.7

TABLE 29.—*Diameter inside bark, in inches, of balsam fir in Maine, at different heights above the ground.*

[Based on 885 trees.]

Diameter breast high (inches).	Height above ground (feet).								
	4.5	10	20	30	40	50	60	70	80
Diameter inside bark (inches).									
40-foot trees.									
6.....	5.7	5.4	4.6	2.9	.....	.....	.....	.....	.....
7.....	6.7	6.1	5.2	3.4	.....	.....	.....	.....	.....
8.....	7.6	6.9	5.8	3.8	.....	.....	.....	.....	.....
9.....	8.5	7.7	6.5	4.2	.....	.....	.....	.....	.....
10.....	9.5	8.5	7.1	4.7	.....	.....	.....	.....	.....
50-foot trees.									
6.....	5.7	5.4	4.7	3.7	2.1	.....	.....	.....	.....
7.....	6.7	6.2	5.4	4.3	2.4	.....	.....	.....	.....
8.....	7.6	7.0	6.1	4.9	2.8	.....	.....	.....	.....
9.....	8.5	7.8	6.9	5.4	3.2	.....	.....	.....	.....
10.....	9.5	8.7	7.6	6.1	3.6	.....	.....	.....	.....
11.....	10.4	9.5	8.3	6.6	4.1	.....	.....	.....	.....
12.....	11.3	10.4	9.1	7.2	4.5	.....	.....	.....	.....

TABLE 29.—*Diameter inside bark, in inches, of balsam fir, in Maine, at different heights above the ground—Continued.*

Diameter breast high (inches).	Height above ground (feet).								
	4.5	10	20	30	40	50	60	70	80
	Diameter inside bark (inches).								
	60-foot trees.								
6.....	5.8	5.5	5.0	4.4	3.3	1.9	-----	-----	-----
7.....	6.7	6.3	5.7	5.0	3.8	2.2	-----	-----	-----
8.....	7.6	7.2	6.5	5.6	4.2	2.4	-----	-----	-----
9.....	8.6	8.0	7.2	6.2	4.7	2.7	-----	-----	-----
10.....	9.5	8.8	7.9	6.8	5.2	2.9	-----	-----	-----
11.....	10.4	9.7	8.6	7.4	5.6	3.2	-----	-----	-----
12.....	11.4	10.5	9.3	7.9	6.0	3.4	-----	-----	-----
13.....	12.3	11.3	9.9	8.4	6.4	3.6	-----	-----	-----
14.....	13.2	12.1	10.5	8.9	6.9	3.9	-----	-----	-----
	70-foot trees.								
8.....	7.6	7.3	6.8	6.1	5.2	3.7	2.1	-----	-----
9.....	8.6	8.1	7.5	6.7	5.6	4.1	2.3	-----	-----
10.....	9.5	9.0	8.2	7.3	6.1	4.5	2.5	-----	-----
11.....	10.5	9.8	8.9	7.9	6.6	4.9	2.6	-----	-----
12.....	11.4	10.6	9.6	8.5	7.1	5.2	2.8	-----	-----
13.....	12.3	11.4	10.3	9.1	7.6	5.5	2.9	-----	-----
14.....	13.3	12.3	11.0	9.7	8.1	5.8	3.1	-----	-----
15.....	14.2	13.1	11.6	10.2	8.5	6.1	3.2	-----	-----
16.....	15.1	13.9	12.2	10.7	9.0	6.4	3.3	-----	-----
	80-foot trees.								
8.....	7.6	7.4	7.0	6.4	5.5	4.4	3.1	1.4	-----
9.....	8.6	8.2	7.7	7.1	6.1	4.9	3.4	1.6	-----
10.....	9.5	9.0	8.4	7.7	6.6	5.4	3.7	1.8	-----
11.....	10.5	9.9	9.1	8.3	7.2	5.8	4.0	1.9	-----
12.....	11.5	10.7	9.9	9.0	7.8	6.3	4.3	2.1	-----
13.....	12.4	11.6	10.6	9.6	8.4	6.8	4.6	2.3	-----
14.....	13.3	12.4	11.4	10.3	9.1	7.2	4.9	2.5	-----
15.....	14.3	13.3	12.1	11.0	9.7	7.7	5.3	2.7	-----
16.....	15.2	14.1	12.8	11.7	10.3	8.2	5.6	2.9	-----
	90-foot trees.								
10.....	9.6	9.1	8.5	7.7	6.7	5.6	4.1	2.5	1.1
11.....	10.5	10.0	9.3	8.5	7.5	6.2	4.6	2.9	1.3
12.....	11.4	10.8	10.1	9.2	8.3	6.9	5.2	3.3	1.5
13.....	12.4	11.7	10.9	10.0	9.0	7.6	5.7	3.7	1.7
14.....	13.4	12.6	11.7	10.8	9.8	8.3	6.3	4.0	2.0
15.....	14.4	13.5	12.5	11.6	10.6	9.0	6.9	4.4	2.1
16.....	15.3	14.3	13.3	12.4	11.4	9.7	7.5	4.9	2.4

CUBIC FOOT VOLUME.

Tables 30 to 32 give the merchantable volume of trees of different diameters and heights inside the bark in cubic feet, cutting to a top-diameter limit of 4 inches in Maine and New York and to 6 inches in New Hampshire.

TABLE 30.—*Merchantable volume of balsam fir in New York, in cubic feet inside the bark, on basis of diameter and height.*

[Average top diameter, 4 inches; based on 947 trees.]

Diameter breast high (inches).	Height of tree (feet).				
	40	50	60	70	80
	Merchantable volume (cubic feet).				
6.....	3.5	4.0	.....	.....	.....
7.....	4.5	5.1	5.9	.....	.....
8.....	5.9	6.8	8.0	9.1	.....
9.....	7.6	8.9	10.4	11.9	.....
10.....	.....	11.2	13.0	14.8	16.6
11.....	.....	13.6	15.6	17.6	19.8
12.....	.....	.....	18.3	20.9	23.6
13.....	.....	.....	21.1	24.5	27.7
14.....	.....	.....	.....	28.4	32.2
15.....	.....	.....	.....	32.9	37.5
16.....	.....	.....	.....	37.8	43.2

TABLE 31.—*Merchantable volume of balsam fir in Maine, in cubic feet inside the bark, on basis of diameter and height.*

[Average top diameter, 4 inches; based on 330 trees.]

Diameter breast high (inches).	Height of tree (feet).				
	50	60	70	80	90
	Merchantable volume (cubic feet).				
8.....	7.7	9.3	10.7	12.2	.....
9.....	9.4	11.3	13.1	14.9	.....
10.....	11.3	13.7	15.9	18.1	.....
11.....	13.5	16.4	19.1	21.6	23.6
12.....	.....	19.4	22.4	25.4	27.7
13.....	.....	22.9	26.1	29.4	32.4
14.....	.....	.....	.....	34.0	37.8
15.....	.....	.....	.....	39.0	44.1

TABLE 32.—*Merchantable volume of balsam fir in Grafton County, N. H., in cubic feet inside the bark, on basis of diameter and height.*

[Top diameter, 6 inches.]

Diameter breast high (inches).	Height of tree (feet).		
	40	50	60
	Merchantable volume (cubic feet).		
6.....	1.9	2.1	.....
7.....	3.9	4.4	5.0
8.....	6.0	6.8	7.8
9.....	8.3	9.5	10.9
10.....	10.8	12.3	14.2
11.....	13.5	15.3	17.6
12.....	.....	18.5	21.2
13.....	.....	23.7	25.0
14.....	.....	.....	28.8
15.....	.....	.....	32.9

CORD VOLUMES.

Tables 33 to 35 give the merchantable volume of trees of different diameters and heights, in cords, for New York, Maine, and New Hampshire. Table 36 gives the number of trees of different heights and diameters per cord for Maine and New York.

In New Hampshire the top diameter is 6 inches and in New York and Maine 4 inches.

TABLE 33.—*Total volume of balsam fir in Maine and New York, in cords, of trees of different diameters and heights.*

[Based on 2,171 trees.]

Diameter breast high (inches).	Height of tree (feet).						
	20	30	40	50	60	70	80
	Cords per tree.						
3.....	0.005	0.008					
4.....	.009	.016	0.022				
5.....	.016	.024	.033	0.042			
6.....		.034	.045	.057	0.068		
7.....		.045	.060	.075	.089	0.105	
8.....			.078	.096	.114	.137	0.168
9.....			.099	.119	.142	.171	.203
10.....			.121	.146	.173	.204	.240
11.....			.146	.178	.206	.241	.278
12.....				.213	.244	.281	.320
13.....					.284	.324	.368
14.....						.366	.419

TABLE 34.—*Merchantable volume of balsam fir in Grafton County, N. H., in cords, of trees of different diameters and heights.*

[Top diameter, 6 inches.]

Diameter breast high (inches).	Height of tree (feet).		
	40	50	60
	Cords per tree.		
6.....	0.019	0.022	
7.....	.040	.045	0.052
8.....	.062	.071	.081
9.....	.086	.099	.113
10.....	.112	.128	.148
11.....	.140	.159	.184
12.....		.192	.221
13.....		.247	.260
14.....			.300
15.....			.342

TABLE 35.—*Number of trees per cord of balsam fir in Maine and New York.*

[Based on 2,171 trees.]

Diameter breast high (inches).	Height of tree (feet).						
	20	30	40	50	60	70	80
	Trees per cord.						
3.....	200.0	125.0	.....	.....	.....	.....	.....
4.....	111.1	62.5	45.5	.....	.....	.....	.....
5.....	62.5	41.7	30.3	23.8	.....	.....	.....
6.....	.....	29.4	22.2	17.5	14.7	.....	.....
7.....	.....	22.2	16.7	13.3	11.2	9.5	.....
8.....	.....	.....	12.8	10.4	8.8	7.3	6.0
9.....	.....	.....	10.1	8.4	7.0	5.8	4.9
10.....	.....	.....	8.3	6.8	5.8	4.9	4.2
11.....	.....	.....	6.8	5.6	4.9	4.1	3.6
12.....	.....	.....	.....	4.7	4.1	3.6	3.1
13.....	.....	.....	.....	.....	3.5	3.1	2.7
14.....	.....	.....	.....	.....	.....	2.7	2.4

Table 36, based on actual measurements of over 73 cords, gives the relation between number of trees, number of sticks, and the solid contents of a stacked cord.

TABLE 36.—*Relation between number of trees, number of sticks, and solid contents of a stacked cord.*

[Based on 56.6 cords.]

Average number of trees per cord.	Average number of 4-foot sticks per cord.	Average number of cubic feet per cord.	Average number of trees per cord.	Average number of 4-foot sticks per cord.	Average number of cubic feet per cord.
9.0	85.3	89.72	7.0	65.7	94.56
8.6	74.8	95.79	7.9	72.8	92.22
8.2	74.9	96.06	7.3	71.6	94.64
7.5	63.6	85.62	9.6	87.5	95.84
9.9	83.7	95.84			

If the middle diameter of the average 4-foot sticks in a stacked cord of wood is known, the solid contents of the cord can be readily ascertained, as it varies with the middle diameter of the average stick in the following manner:

TABLE 37.—*Relation between solid contents of a stacked cord and middle diameter of average stick.*

Middle diameter of average stick (inches).	Cubic feet per cord.
6.5	89
7.0	92
7.5	94
8.0	96
8.5	98

CONVERTING FACTORS OF STACKED MEASURE INTO CUBIC FEET.

The following factors can be used for converting stacked measure into cubic measure:

For cords made up of billets 4 feet long and from 4 to 7 inches in diameter, 0.72.

For cords made up of billets 4 feet long and from 8 to 12 inches in diameter, 0.76.

In order to convert a cord of ordinary pulpwood into cubic measure, 128 feet should be multiplied by 0.74, the average converting factor for pulpwood.

FORM FACTORS.

Tables 38 and 39 give breast-high form factors for Maine and for New York.

TABLE 38.—*Form factors (breast high) for New York.*

Diameter breast high (inches).	Height of tree (feet).						
	20	30	40	50	60	70	80
	Form factor.						
3.....	0.552	0.551					
4.....	.547	.546	0.546				
5.....	.542	.541	.541	0.539			
6.....		.535	.534	.533	0.530	0.527	
7.....		.529	.527	.525	.522	.520	0.518
8.....			.519	.516	.514	.512	.510
9.....				.507	.505	.503	.501
10.....				.498	.496	.494	.492
11.....				.488	.486	.484	.483
12.....					.475	.474	.473
13.....					.465	.464	.463
14.....					.454	.454	.453
15.....					.445	.444	.444
16.....					.436	.435	.435

TABLE 39.—*Form factors (breast high) for Maine.*

Diameter breast high (inches).	Height of tree (feet).				
	40	50	60	70	80
	Form factor.				
7.....	0.531	0.539	0.546	0.553	
8.....	.517	.525	.531	.541	0.549
9.....	.502	.510	.519	.528	.537
10.....		.484	.504	.515	.525
11.....		.478	.490	.501	.512
12.....			.475	.488	.500
13.....			.460	.474	.487
14.....			.444	.459	.473
15.....			.428	.444	.459
16.....			.412	.430	.445

BARK VOLUMES.

Table 40 gives the volume of bark of trees of different diameters and heights. On the whole, bark makes up about 10.6 per cent of the total volume of the tree.

TABLE 40.—*Volume of bark for trees of different diameters and heights in Maine.*

Diameter breast high (inches).	Height of tree (feet).				
	40	50	60	70	80
	Volume of bark (cubic feet).				
7.....	0.6	0.7	0.9	1.0	1.5
8.....	.7	.9	1.1	1.3	1.9
9.....	.9	1.1	1.4	1.6	2.3
10.....		1.3	1.6	2.0	2.7
11.....		1.6	1.9	2.3	3.1
12.....			2.2	2.7	3.6
13.....			2.5	3.1	4.0
14.....			2.8	3.4	4.5
15.....			3.2	3.8	5.0
16.....			3.5	4.2	

BOARD-FOOT VOLUMES.

Tables 41 and 42 give the merchantable volume in board feet (Scribner, Dimick, Maine, and Bangor rules) for trees of different diameters and heights.

TABLE 41.—*Volume of trees of different diameters and heights—Scribner Decimal C and Dimick rules.*

[Based on taper curves, scaled as 8 and 16 foot logs. Stump height assumed, 1 foot.]

SCRIBNER DECIMAL C.

Diameter breast high (inches).	Swamp.				Hardwood slope and flat.						
	Height of tree (feet).				Diam- eter inside bark of top (inches).	Height of tree (feet).					Diam- eter inside bark of top (inches).
	40	50	60	70		40	50	60	70	80	
	Volume (board feet).					Volume (board feet).					
7	14	17	20	22	5.8	13	19	27	40	5.8	
8	19	23	27	32	5.9	21	26	33	48	5.9	
9	24	31	37	44	6.1	29	34	41	56	6.0	
10		39	48	57	6.2	38	45	52	60	6.1	
11		48	60	73	6.4		56	65	75	6.2	
12		57	73	92	6.6		69	80	92	6.3	
13		66	87	110	6.8		82	95	111	6.4	
14								111	132	6.4	
15								127	153	6.5	
16								144	174	6.6	

DIMICK.

	Volume standards.					Volume standards.				
	0.09	0.10	0.12	0.15		0.11	0.13	0.15	0.24	
7.....					5.8					5.8
8.....	.13	.15	.18	.21	5.9	.15	.18	.21	.24	5.9
9.....	.17	.21	.24	.28	6.1	.19	.23	.28	.33	6.0
10.....		.26	.31	.36	6.2	.24	.29	.35	.41	6.1
11.....		.32	.38	.47	6.4		.36	.43	.50	6.2
12.....		.38	.46	.59	6.6		.44	.51	.59	6.3
13.....		.44	.54	.71	6.8		.52	.60	.70	6.4
14.....								.71	.82	6.4
15.....								.82	.94	6.5
16.....								.94	1.07	6.6

TABLE 42.—*Volume of trees of different diameters and heights—Bangor and Maine rules.*BANGOR RULE.¹

Diameter breast high (inches).	Height of tree (feet).						Diameter inside bark of top (inches).
	40	50	60	70	80	90	
	Volume (board feet).						
7	15	21	27	-----	-----	-----	5.9
8	23	29	38	50	64	-----	6.2
9	32	40	49	62	78	-----	6.4
10	42	51	62	76	93	109	6.6
11	-----	63	77	94	110	129	6.8
12	-----	77	94	113	132	154	7.0
13	-----	-----	111	135	160	185	7.1
14	-----	-----	129	159	191	223	7.2
15	-----	-----	-----	186	226	268	7.3
16	-----	-----	-----	215	262	317	7.4

MAINE RULE.²

7	15	21	26	-----	-----	-----	5.9
8	24	32	40	50	60	-----	6.0
9	34	44	54	65	76	-----	6.1
10	46	57	69	81	94	106	6.2
11	-----	71	85	99	114	129	6.2
12	-----	86	102	120	138	157	6.2
13	-----	-----	121	143	167	193	6.3
14	-----	-----	140	166	200	236	6.3
15	-----	-----	-----	191	236	283	6.3
16	-----	-----	-----	215	271	333	6.4

¹ Based on taper curves, scaled as 16-foot logs. Stump height assumed, 1 foot.² Based on taper curves, scaled as 8 and 16 foot logs. Stump height assumed, 1 foot.

RATIO BETWEEN BOARD AND CUBIC MEASURE.

Table 43 gives the ratio between board measure (Maine rule) and cubic feet.

TABLE 43.—*Ratio between board measure (Maine rule) and cubic feet (merchantable contents).*

[Based on 330 trees.]

Diameter breast high (inches).	Board feet per cubic foot.	Diameter breast high (inches).	Board feet per cubic foot.
7	3.0	12	3.4
8	3.2	13	3.4
9	3.3	14	3.5
10	3.3	15	3.5
11	3.4	16	3.5

CLEAR LENGTH AND USED LENGTH.

Tables 44 and 45 give the clear length and the used length of trees of different diameters in Maine and New York.

TABLE 44.—*Clear length and used length of balsam fir of different heights and diameters in New York.*

Diameter breast high (inches).	Hardwood slope.			Flat.			Swamp.		
	Total height.	Clear length. ¹	Used length. ²	Total height.	Clear length. ³	Used length. ⁴	Total height.	Clear length. ⁵	Used length. ⁶
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
6.....	48	19	27	48	24	26	45	17	25
7.....	53	22	31	52	25	30	49	21	28
8.....	57	24	35	56	26	33	52	23	31
9.....	61	26	38	60	27	37	55	24	33
10.....	63	27	42	62	28	40	58	25	36
11.....	66	28	44	65	29	43	60	25	39
12.....	69	29	47	67	29	46	62	25	43
13.....	71	30	49	70	30	48	64	25	46
14.....	73	31	51	72	31	50	66	.....	.....
15.....	75	32	52	74	33	52	.....	.....	.....
16.....	78	32	54	76	34	53	.....	.....	.....

¹ Based on 440 trees.

² Based on 560 trees.

³ Based on 386 trees.

⁴ Based on 333 trees.

⁵ Based on 344 trees.

⁶ Based on 202 trees.

TABLE 45.—*Clear length and used length of balsam fir of different heights and diameters in Maine.*

[Clear length based on 407 trees; used length based on 379 trees.]

Diameter breast high (inches).	Total height.	Clear length.	Used length.	Diameter breast high (inches).	Total height.	Clear length.	Used length.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
6.....	52	.....	.....	12.....	73	40	29
7.....	57	38	22	13.....	75	40	30
8.....	62	39	23	14.....	77	40	31
9.....	65	39	25	15.....	79	40	32
10.....	68	40	26	16.....	80	40	33
11.....	71	40	27	17.....	82	40	34

PER CENT OF CULL AND WASTE.

The average cull within merchantable dimensions, that is, for the portion of the trees from stump to 4-inch top, constitutes on the average about 11.2 per cent of the merchantable yield. The top and stump form about 8.4 per cent of the total volume; the bark, 10.6 per cent. In other words, about 19 per cent of the total volume of the tree at present remains unutilized. Of the remaining merchantable part of the tree, 11.2 per cent must be allowed for cull.

YIELD.

ON SMALL SAMPLE AREAS.

The yield of balsam fir fluctuates within wide limits. Since it grows with spruce and other species, its yield naturally depends upon the degree of admixture. An idea of what can be expected from balsam fir may best be formed from pure stands in the swamps or flats. For New York a good average for large flats, cutting for pulp to 7 inches diameter breast high, is 15 cords to the acre. Exceptional areas have cut as high as 40 cords. In swamps, while the stands are usually dense, the individual trees are of small size, and the yield per acre on the whole is smaller than on the flats. Ten cords to the acre may be considered a good average. On the hardwood slope the yield varies more than for any other type; on an average it runs about 7 cords to the acre.

In Maine the yield runs much higher than in New York. Pure stands of balsam fir on flats will yield, as a general rule, about 25 cords to the acre and occasionally as high as 30 cords for stands from 70 to 100 years old. On the hardwood slope the yield is only half of that on the flat, about 12.5 cords to the acre.

Tables 46 and 47 give the results of actual measurements of yield in the Adirondacks and in Maine.

TABLE 46.—*Yield of balsam fir in New York, based on 10 sample plots, covering an area of 9 acres.*

SWAMP.

Average age of merchantable stand (years).	Total yield per acre.		Average number of merchantable trees per acre.	Mean annual increment per acre.	
	<i>Cubic feet.</i>	<i>Cords.</i>		<i>Cubic feet.</i>	<i>Cords.</i>
80.....	922	10.2	88	11.5	$\frac{1}{8}$

FLAT.

90.....	1,270	13.2	102	14.1	$\frac{1}{8}$
90.....	1,312	15.3	110	14.6	
90.....	1,443	15.0	140	16.0	
Average.....	1,342	14.4	117	14.9	$\frac{1}{8}$

HARDWOOD SLOPE.

70.....	444	4.6	36	6.3	$\frac{1}{8}$
70.....	685	7.1	60	9.8	
70.....	760	8.0	49	10.9	
80.....	713	7.7	55	8.9	
70.....	607	6.4	46	8.7	
70.....	928	9.7	86	13.3	
Average.....	690	7.3	55	9.6	$\frac{1}{8}$

TABLE 47.—Yield of balsam fir in Maine, based on 22 sample plots, covering an area of 6 acres.

FLAT.

Plot No.	Age of stand.	Trees cut per acre.	Total yield.	Yield without bark.	Merchantable volume.		Mean annual increment per acre.
			<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Cords.</i>	<i>Cubic feet.</i>
1.....	90	152	2,395	2,156	2,149	22.6	26.6
2.....	90	144	2,763	2,501	2,460	25.9	30.7
3.....	70	160	2,543	2,268	2,330	24.5	36.3
4.....	70	100	1,357	1,212	1,239	13.0	19.4
5.....	80	168	2,937	2,614	2,704	28.4	36.7
6.....	90	200	3,739	3,364	3,504	36.8	41.5
7.....	90	160	3,010	2,674	3,010	31.6	33.4
8.....	90	132	2,936	2,627	2,675	28.1	32.6
9.....	90	136	2,789	2,473	2,512	26.4	31.0
10.....	90	86	1,408	1,261	1,259	13.2	15.6
11.....	70	144	2,811	2,435	2,590	28.3	40.1
12.....	90	120	2,115	1,896	1,910	20.0	23.5
13.....	90	168	2,689	2,388	2,497	26.2	29.8
Average.....		144	2,575			25.0	¹ 30.5

HARDWOOD SLOPE.

14.....	90	80	1,666	1,490	1,547	16.2	18.5
15.....	80	88	1,342	1,214	1,240	13.0	16.8
16.....	80	60	1,034	930	957	10.0	12.9
17.....	80	68	963	868	881	9.2	12.0
18.....	90	96	1,861	1,668	1,683	17.7	20.6
19.....	90	122	2,165	1,945	1,933	20.3	24.0
20.....	80	48	534	485	480	5.0	6.6
21.....	100	62	1,170	1,040	1,050	11.0	11.7
22.....	90	52	1,226	1,085	1,112	11.7	13.6
Average.....		75	1,329			12.6	² 15.2

¹ Equals one-third cord.² Equals one-sixth cord.

OVER LARGE AREAS.

The figures in Tables 46 and 47 represent the yield of carefully selected small areas of balsam-fir stands. Over large areas, including all types of land, the yield is much smaller. The results of measurements of nearly 60,000 acres in three townships of Hamilton County, N. Y., gave an average yield per acre for all types of coniferous lands of 4.4 standards, or 1.5 cords (Table 48).

TABLE 48.—Average yield of balsam fir over large areas in Hamilton County, N. Y.

[Cutting to a limit of 10 inches and over in diameter breast high.]

Type.	Area (acres).	Total yield (standards).	Average yield per acre (standards).
Township 5:			
Swamp and spruce land.....	10,376	39,676.58	3.82
Do.....	4,405	22,677.90	5.15
Do.....	2,072	10,675.35	5.15
Total.....	16,853	73,029.83	
Average per acre.....			4.30
Township 41:			
Swamp and spruce land.....	6,960	19,585.20	2.81
Do.....	1,869	6,397.76	3.42
Do.....	10,982	57,755.88	5.26
Total.....	19,811	83,738.84	
Average per acre.....			4.20
Township 6:			
Swamp and spruce land.....	122	52.92	.43
Do.....	12,156	55,374.84	4.56
Do.....	3,609	15,618.26	4.33
Do.....	2,779	18,391.98	6.62
Do.....	1,332	5,740.92	4.31
Do.....	1,464	4,832.88	3.30
Total.....	21,462	100,011.80	
Average per acre.....			4.70

Measurements of nearly 17,000 acres in Herkimer County, N. Y., gave an average yield for all types of coniferous land (both virgin and cut-over) of only 1.4 standards. The yield for swamp land, which is largely balsam-fir land, ran on an average as high as 5.42 standards, or nearly 2 cords to the acre. (Table 49.)

TABLE 49.—Average yield of balsam fir over large areas in Herkimer County, N. Y.

[Cutting to a limit of 10 inches in diameter breast high.]

Type.	Area (acres).	Total yield (standards).	Average yield per acre (standards).
Spruce land:			
Virgin.....	3,732	4,105	1.10
Cut-over.....	4,158	5,073	1.22
Total.....	7,890	9,178	1.16
Swamp:			
Virgin.....	210	1,187	5.65
Cut-over.....	161	824	5.12
Total.....	371	2,011	5.42
Grand total.....	8,261	11,189	
Average.....			1.40

In New Hampshire, measurements of over 2,000 acres gave an average yield of 482 board feet for balsam and 1,772 board feet for spruce (New Hampshire rule), or nearly 0.8 of a cord of balsam fir per acre, forming about 27 per cent of the entire spruce yield. (Table 50.)

TABLE 50.—*Average yield of balsam fir over large areas in Grafton County, N. H.*

[New Hampshire log rule.]

Area (acres).	Total yield.		Average yield per acre.	
	Spruce.	Balsam.	Spruce.	Balsam.
	<i>Board feet.</i>	<i>Board feet.</i>	<i>Board feet.</i>	<i>Board feet.</i>
107.....	124,976	63,879	1,168	597
112.....	273,840	93,520	2,445	835
115.....	94,645	10,925	823	95
135.....	170,235	14,715	1,261	109
141.....	38,211	846	271	6
190.....	651,510	67,260	3,429	354
574.....	1,402,856	392,616	2,444	684
259.....	437,192	172,494	1,688	666
446.....	617,264	174,386	1,384	391
154.....	146,146	84,700	949	550
Total (2,233).....	3,956,875	1,075,341	1,772	482

INCREMENT.

The sample plots in New York and Maine (Tables 46 and 47) showed that mature stands of balsam fir produce annually from one-sixth to one-third of a cord of wood per acre. At such a rate the poorest land produces 10 cords per acre in 60 years, and the better land 10 cords of pulpwood every 30 years. This annual increment is very low as compared with the yields obtainable under forest management. The increment should be at least two-thirds of a cord, or possibly 1 cord a year.

MANAGEMENT.

EFFECT OF PAST CUTTING.

Balsam fir is so closely associated with spruce wherever it occurs that it is impossible to outline a system of management for one species that will not at the same time affect the other. Both species are almost constantly contesting for the occupancy of the ground. If left to themselves the greater tolerance and more persistent growth of spruce would undoubtedly in the long run secure for it the predominance in the present forests as they formerly did in the virgin stands, before the interference of man. Lumbering, however, has turned the scale of the struggle between the different species in favor of trees of smaller commercial importance. Thus, white pine, the most valuable species of the northeastern forests, was taken first, with the result that it was unable to hold its own against its competitors. Then came the turn of spruce. The latter, in many

cases, is now being cut for the third time, smaller logs being taken at each new lumbering. Balsam, on the other hand, has been spared until recently and thus given a chance to spread at the expense of spruce. These facts are well brought out by measurements taken in Maine on 20 acres of virgin and 20 acres of forest cut over once. The difference in the representation of the two species in virgin and cut-over forest is especially striking in the trees of small diameters, since not enough time has elapsed after cutting to affect in any great degree the large trees.

TABLE 51.—Average number of spruce and balsam fir up to 12 inches in diameter breast high on an acre of virgin and cut-over forest in Maine.

Diameter breast high (inches).	Virgin.		Cut-over.	
	Spruce.	Balsam.	Spruce.	Balsam.
2.....	29.2	12.8	13.0	35.2
3.....	51.0	12.0	8.6	23.4
4.....	44.2	11.8	7.4	21.4
5.....	39.4	8.6	5.4	19.8
6.....	24.4	7.0	4.4	17.6
7.....	23.2	6.4	4.2	14.6
8.....	17.8	6.4	4.0	13.0
9.....	17.4	2.2	3.4	10.2
10.....	14.2	2.0	3.0	9.8
11.....	9.2	1.6	2.6	4.6
12.....	6.4	1.2	2.6	4.0
Total.....	276.4	72.0	58.6	173.6

The rapid spreading of balsam over cut or burnt spruce land is due chiefly to its prolific seeding, love for light, and rapid growth. In this respect, as in many others, balsam occupies the same place among the northeastern conifers as aspen does among the deciduous species. It is the first of all conifers to take possession of openings, burnt or cut-over land, and at present outnumbered spruce in the young growth and smaller diameters throughout the northern woods. Table 52 shows the number of spruce and fir trees on an average acre, based on actual measurements of 955 acres in the forests of Maine. The measurements were taken on the slope type, where spruce is more at home than is balsam.

TABLE 52.—Number of spruce and fir trees on an average acre, based on 952 acres in Maine.

Diameter breast high (inches).	Spruce.	Balsam fir.	Diameter breast high (inches).	Spruce.	Balsam fir.
2.....	9.1	17.8	10.....	4.0	6.1
3.....	9.9	18.7	11.....	3.6	3.9
4.....	9.1	18.0	12.....	3.4	2.3
5.....	7.2	15.9	Total.....	66.1	124.6
6.....	5.8	13.2			
7.....	5.4	11.2	Trees, 2 inches to 8 inches, inclusive.....	51.1	104.4
8.....	4.6	9.6			
9.....	4.0	7.9			

SILVICULTURAL SYSTEMS OF CUTTING.

Upon the methods of cutting adopted in spruce stands will depend whether the future forest will be chiefly spruce or balsam or whether there will be future growth at all. In discussing these methods the economic limitations and specific conditions which may affect their application are not considered. These must necessarily differ for each particular forest tract. In a general discussion of the silvicultural system adapted to spruce and balsam it is possible to lay down only general principles.

Natural reproduction may be secured in spruce-balsam fir stands by two methods: (1) Clear cutting and (2) gradual cuttings.

CLEAR CUTTING WITH NATURAL REPRODUCTION.

In clear cutting, natural reproduction from stands adjoining the cutting must be relied upon to restock the area. The size and form of the clear-cut areas are therefore factors in the success of the reproduction. If natural reproduction is desired, the greatest width of the

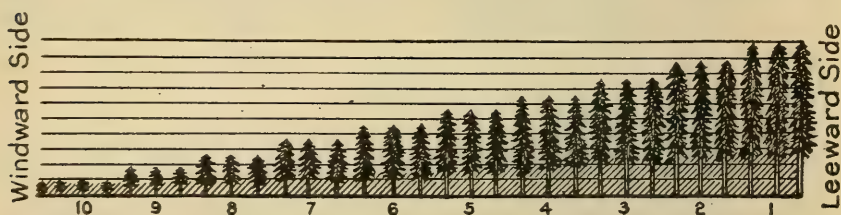


FIG. 6.—Results secured by logging on the leeward side of balsam fir-spruce stands. The youngest stands are found on the windward side and deflect the wind upward, preventing windfall among the older trees.

area to be cut clear in spruce-balsam fir stands should not exceed double the height of the adjoining stand from which reseedling is expected. For example, if the average height of a spruce and balsam-fir stand is 75 feet, then the width of the area which is to be cut clear should not be greater than 150 feet. The length of the area does not affect the natural reproduction and should depend, therefore, upon the amount of timber to be cut, convenience of logging, and similar considerations. In general, then, clear cutting with natural reproduction in spruce-balsam fir stands should take the form of long narrow strips.

Since both spruce and balsam are shallow-rooted trees and therefore subject to windfall, logging operations should as far as possible always begin on the leeward side of the mature timber, and proceed against the wind. If logging were to begin on the windward side there would always be danger from windfall in the stands adjoining the logged area. When the entire forest is cut over in this way, the youngest stands will be on the windward side, their tops forming a gradual ascending plane (fig. 6). The wind is thus deflected

upward, without breaking into the older stands. Logging from the leeward side also permits the seed to be carried by the wind from the mature stands to the logged-over area.

Successive strips.—No matter how narrow the strips are made, they should not be cut one after another every year, unless there is sufficient young growth to insure a full stand. Spruce and balsam do not bear seed every year, but at intervals of from four to six years. If the strips are cut one after another every year, the logged areas could not be reproduced for lack of seed. The stand adjoining the logged area should be cut only after the latter has been fully reseeded, or at the end of four to six years. With this method of cutting the logging will have to be scattered over a fairly wide territory.

Alternate strips.—To avoid too great a scattering of the cuttings, which necessarily increase the cost of logging, the strips may be cut

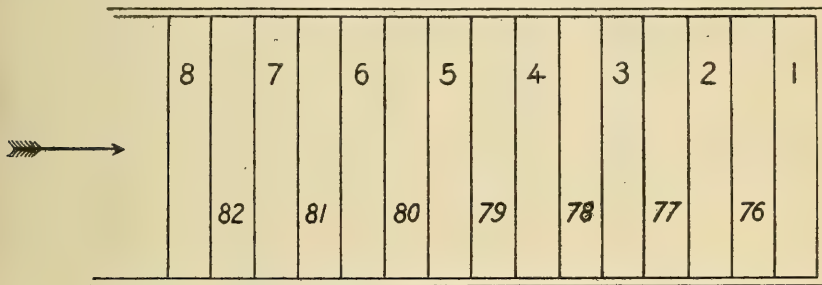


FIG. 7.—Cutting in alternate strips. During the first half of the rotation only alternate strips are cut. The remaining strips are cut over during the second half of the rotation. At the time the remaining strips are cut the first strips are 75 years old and are capable of reseeding the adjoining clearings.

alternately instead of one after another, at an interval of from four to six years. In applying this method, the entire tract is divided into strips narrow enough to insure natural reproduction. The tract is cut over twice. The first time only alternate strips are cut; the second time, the remaining strips. Every year as many strips may be cut as are needed to secure the desired amount of timber. Under this method the timber tract, after it has been entirely cut over, would consist of strips of timber in which two adjoining strips would differ in age by as many years as it took to cut over all of the alternate strips. If 150 years is decided upon as the rotation for a mixed stand of spruce and balsam fir, the entire tract would be cut over in 150 years, and the alternate strips would be cut over within the first 75 years. The strips that were cut first would then be 75 years old when the adjoining strips are cut. At the age of 75 years both spruce and balsam bear seed prolifically, and will readily reseed the adjacent clearings made by cutting the remaining strips (fig. 7).

Cutting in alternate strips tends to concentrate logging, since as much timber may be cut per acre as under the present methods of

culling the forest of trees of certain diameters. It requires, however, great regularity and exactness in logging operations, and may therefore present difficulties, although it is being practiced to a considerable extent in private and State spruce forests abroad.

Thinned and partially cleared strips.—Another modification of the system of clear cutting in strips is especially applicable to large stands of mature timber. Watersheds, or other logging units large enough to allow logging on the same area for a period of five or six years, are divided into strips, all of which are cut over within the five or six year period, but only for two-thirds of their full width. Thus, if the width of the strips is 150 feet, each strip is cut only 100 feet. On the remaining 50 feet of each strip the timber is merely thinned (fig. 8). As logging operations on the area will go on for five or six years, there should be one or two good seed years during which the logged areas will be reproduced from the adjoining 50-foot

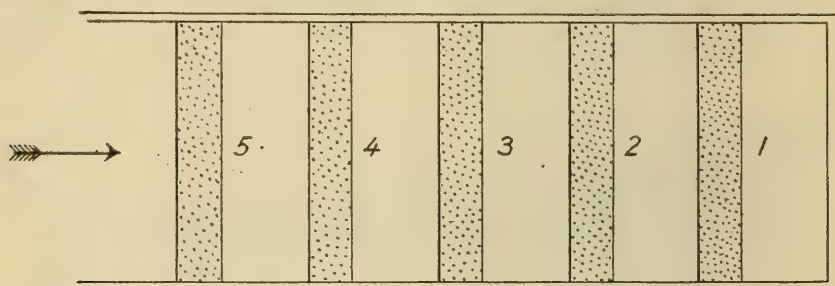


FIG. 8.—Partially cleared and thinned strips. Each strip is cut only for two-thirds of its width. On the remaining one-third the timber is only thinned. Reproduction takes place on the adjoining clearings and under the thinned stand. When reproduction is secured, the remaining one-third of the strip is cut clean. The entire logging area is reproduced within five or six years.

strips of timber. Since 50-foot strips are thinned, reproduction will occur on them. As soon as young growth appears on the clearings and under the trees left uncut, the 50-foot strips are also taken, and the entire area is thus cut and reproduced within a few years. This method of cutting is simple and, under favorable conditions, practical as a logging proposition. The great danger is from windfall, to which thinned stands are particularly susceptible.

While often, as in cutting for pulp, clear cutting in strips is the best method, even with the greatest precautions cleared strips often fail to reproduce naturally with the desired species. No matter what modification of the system is practiced, the narrower the strip the greater are the chances for successful natural reproduction. When abundant young growth exists under the old trees, clear cutting need not be in the form of strips, but may cover the entire area bearing reproduction.

Clear cutting in strips must naturally lead to an increase of balsam in the second growth, since it is a prolific seeder and requires more

light than does spruce. This is especially true in the case of alternate or successive strips. With partially cleared and thinned strips, however, which are cut practically at the same time, the reproduction of balsam fir can be reduced in favor of spruce if thinning is confined largely or exclusively to balsam fir, thus decreasing its participation in reseeding the ground.

CLEAR CUTTING, WITH ARTIFICIAL REPRODUCTION.

Still another silvicultural method to which both spruce and balsam fir are adapted, particularly for pulp, is clear cutting, with subsequent planting. Such a system, however, presupposes intensive management and a considerable initial outlay of money. The planting of red spruce and balsam fir would be hardly advisable for both silvicultural and financial reasons, because of the former's extremely slow growth and the latter's comparatively inferior qualities. If planting is to be done, it would be better to use more valuable and promising species, such as Norway or possibly white spruce. The cost of establishing a stand artificially is the same whether valuable or inferior species are used. For these reasons clear cutting, with artificial reproduction, would hardly be a profitable undertaking, at least for the balsam fir. The justification for retaining balsam fir in the future stands must be in the ease with which it can be reproduced naturally and cheaply.

GRADUAL CUTTING.

Selection in groups.—Spruce stands are best managed by gradual cuttings. This is essentially the method used in the old-time logging operations, when only the largest trees could be used, and is in vogue now on a number of large spruce tracts owned by pulp and paper companies. Only the larger mature trees or trees of a certain character are taken, and the rest left on the ground for future logging.

Natural reproduction of spruce and balsam is readily secured under this method of cutting if the following rules are observed:

1. In logging, the trees should be removed not singly but in small groups. The removal of such groups of trees will make small openings, or "holes," in the forest, which are more readily stocked than openings made by the removal of single trees. When single trees are cut, the openings are soon closed by the growth of side branches of the neighboring trees, and the young growth that appears is soon either shaded out or stunted. Openings, or "holes," in the forest formed by the removal of groups of trees a quarter of an acre or less in extent receive abundant seed from the surrounding trees, yet have enough light for a vigorous and normal development of the reproduction that springs up.

2. The same ground should not be logged too often; say, not oftener than every 10 or 20 years. Frequent logging over the same area prevents the firm establishment of young growth.

3. Keep out fires from the logged-over areas.

This system of gradual cutting, which may be called a selection system in groups, is decidedly the most practical, simplest, and safest so far as securing natural reproduction of spruce and balsam is concerned. Under it, spruce reproduction is favored at the expense of balsam, since the openings are small and the light conditions more favorable to spruce than to balsam. The greatest advantage of the system, however, is the protection which it affords against windfall—a very important consideration in all spruce cuttings.

The system differs from the method of logging practiced 25 to 30 years ago only in that the trees are cut in small groups instead of singly. Many of the old cuttings, when fires were kept out, have been cut over for the second and third time. Experience shows that no forest has ever been ruined by such a method of cutting. It is the recent logging, which amounts to practically clear cutting, especially when followed by fires, which has reduced large areas of timberland to a state where artificial planting or sowing is the only means of bringing them back to forest.

By clear cutting small groups, opportunity is afforded for utilizing all the merchantable timber, especially if the openings are made in the older and more mature stands. At the same time, forest conditions are preserved which are favorable for natural reproduction. The danger from windfall under this method is almost entirely avoided.

Cutting to a diameter limit.—Cutting in strips or selection cutting in groups requires a careful selection of the logging areas and expert technical knowledge. Wherever such knowledge can not be had, light cutting over the entire logging area may roughly answer the requirements of natural reproduction of both spruce and balsam fir. The higher the diameter limit for both species the more favorable will be the conditions for natural reproduction. The diameter limit should be raised in thin stands and lowered in dense ones, the main point being not to open the stand too heavily and destroy the conditions under which natural reproduction takes place. Although by cutting balsam fir to a lower diameter than spruce some advantage may be given spruce in reseeding the ground, yet under such a rough system it is difficult to control the conditions under which one or the other species can best come up; the preponderance of spruce or balsam fir in the future stand must therefore be left largely to chance.

ROTATION.

The difference in the rate of growth of balsam fir and spruce has a direct bearing upon the choice of rotation or proper time of cutting the two species. From the tables it is evident that balsam fir, if its growth is to be utilized to the fullest advantage, should not be cut before it reaches an age of about 100 or 125 years, or a diameter of 12 to 14 inches breast high. Cutting balsam fir below 6 or 7 inches means utilization of trees which are still making a fair growth. Spruce, on the other hand, should not be cut before it is 175 or 200 years old, since most of its growth is made at the age of from 100 to 200 years. The rotation for balsam fir, therefore, should be about 100 years, and for spruce at least 175 years. These rotations, of course, would be applicable only if balsam fir and spruce were grown separately. Since they usually grow together, the practical application of these different rotations would simply mean that in cutting over a virgin stand of spruce and balsam fir, the fir should be cut to a younger age, only the older spruce being removed.

SUMMARY.

1. Balsam fir forms, on an average, from 10 to 15 per cent of the entire red-spruce stand, or 5,355 million board feet.
2. Under present methods of cutting, balsam fir is increasing at the expense of red spruce in the second growth throughout the entire range of the two species.
3. Balsam-fir wood, while to some extent inferior to spruce for construction material, has a definite place in the pulp and lumber industries.
4. Balsam fir grows much faster throughout its entire life than spruce, but is shorter lived and reaches maturity long before the latter.
5. Balsam fir should be cut at an age of from 100 to 125 years, while spruce, as it grows at present in the wild wood, should be cut at an age of from 175 to 200 years.
6. The annual increment per acre of balsam fir throughout its range varies from one-sixth to one-third of a cord, or 1 cord in from three to six years.
7. The best silvicultural system of cutting is that of selection cutting in small groups. The natural reproduction of both spruce and balsam fir is assured under this system, with the possibility of increasing the proportion of spruce in the new stand.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 56



Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
January 28, 1914.

A SPECIAL FLASK FOR THE RAPID DETERMINATION OF WATER IN FLOUR AND MEAL.

By JOHN H. COX,

Assistant in Grain Standardization.

INTRODUCTION.

The special flask which is described in this bulletin is used in connection with the Brown-Duvel tester described in Circular No. 72 of the Bureau of Plant Industry, United States Department of Agriculture, entitled "A Moisture Tester for Grain and Other Substances and How to Use It," by Dr. J. W. T. Duvel. The special flask, shown in figure 1, has double walls and was developed for commercial work so that a quick and accurate test could be made of finely ground material, such as flour and meal. The single-walled flask described in the circular mentioned is not suitable for testing finely ground substances, as it does not always give accurate results. The meal when tested in such a flask frequently burns badly at the bottom, and the flask does not clean well and soon breaks, while the double-walled flask may be cleaned without trouble and does not break easily.

One of the principal causes why corn meal and other finely ground materials deteriorate is the water which they contain. The manufacturers of these finely ground products can largely eliminate the excess water in their meal and flour by proper precautions. The amount of water in flour or meal can easily be tested in a few minutes by the use of this special flask, thereby determining whether they contain too much water for safe transportation or storage.

The tester consists of two or more compartments, so that one or more duplicate sample tests can be run at the same time. There is a flask for each compartment and a gas, alcohol, or gasoline burner beneath each one. Figures 2 and 3 show an external view of a standard 6-compartment water tester ready for use.

DESCRIPTION OF THE SPECIAL FLASK.

The flask, the dimensions of which are shown in figure 1, is double walled and can be made of copper or glass. The inner flask has a capacity of approximately 900 cubic centimeters and the space between the two walls should hold not less than 250 nor more than 300 c. c. If the flasks are made of copper, the thickness of the copper before it is spun should be 22 thousandths of an inch or 16 ounces to the square foot. The copper flasks will have to be made in two sections and soldered together in the middle with a very hard solder. The soft solder commonly used by plumbers is not suitable for this work. Success with these flasks has been attained only when they were soldered together with a silver solder. The neck of the flask must be of but one thickness of copper, for if it is too heavy it will melt the rubber stoppers.

The glass flasks when made in accordance with the proper specifications will give as accurate results as the copper ones. They should be made of the best grade of resistant glass and well annealed, and the necks should be sufficiently heavy to stand tight corking. When 150 c. c. of oil is poured in between the two

walls, the top of the oil should be about halfway up the sides of the flasks. If the flasks do not meet these specifications they should not be used.

HOW TO MAKE A WATER TEST OF FLOUR OR MEAL.

To make a water test pour 150 c. c. of oil in the inner flask and then 150 c. c. of oil between the two walls. Weigh an average sample of 50 grams on scales that are sensitive to at least one-twentieth of a

gram and put it into the inner flask by means of a long funnel, so as to drop the material well down into the inner flask; otherwise, the material will collect around the neck and will be liable to fill up the tube which leads from the flask to the condensing tube.

SPECIFICATIONS FOR THE THERMOMETER.

The thermometer should be approximately 13 inches long and nine thirty-seconds of an inch in diameter, with a bulb approximately three-fourths of an inch in length. The thermometer should be grad-

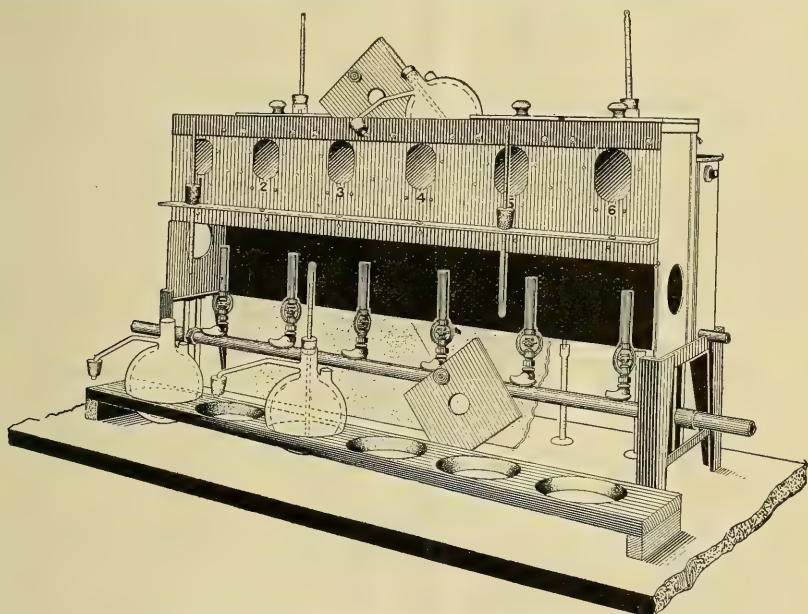


FIG. 2.—A 6-compartment Brown-Duvel moisture tester.

uated in whole degrees from 0° to 210° C., with the graduations etched on a stem having a white background.

ADJUSTMENT OF THE THERMOMETER.

The thermometer is more easily adjusted in the copper flask by first putting the bulb in flour, leaving a fine white coating of the substance on the thermometer. It is then put into the flask and quickly withdrawn, so as to see the height of the oil on the bulb, which should be so placed in the flask that it is approximately three-fourths covered with oil, as shown in figure 3. If the thermometer is not properly adjusted, the results will be inaccurate.

DESCRIPTION OF THE GRADUATE AND HOW TO READ IT.

The special graduate shown in figure 4, used when a 50-gram sample is tested, is just one-half the volume of the graduate in regular

use and gives the percentage of water direct without multiplying by two, which must be done in employing the one commonly used.

Usually a small quantity of oil is carried over into the measuring cylinder and collects on the surface of the water, so that the readings should be made at the bottom of the meniscus between the oil and the water, as shown in figure 4. After the test has been made the

graduate should be emptied and wiped dry. A cleaner can be made by doubling and twisting a wire which has a fair degree of stiffness and wrapping absorbent cotton or waste around the end above the hooks. The ends of the wire should be turned around in a half circle, so as to make a convenient hook to catch the cotton or waste, as illustrated in figure 5.

OIL USED IN MAKING THE TEST.

The oil to be used should be the same as that specified in Circular No. 72 of the Bureau of Plant Industry, in which it is described in part as follows:

In making tests a good grade of mineral engine oil should be used. The oil must be free from water, should have a flashing point

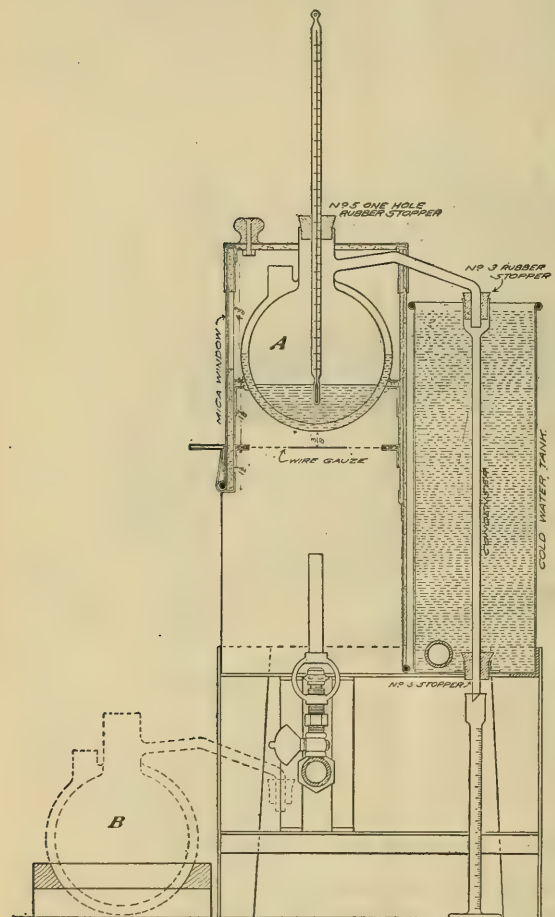


FIG. 3.—Sectional view of the Brown-Duvel moisture tester, showing the various parts connected for use. *A*, Distillation flask in position, three-eighths of an inch above the wire gauze; *B*, distillation flask in the wooden rack used only during the filling.

in open cup of approximately 200° to 205° C. (392° to 401° F.), and preferably a viscosity between 10 and 15 (Engler) at 20° C. (68° F.). After the tests are completed and while the oil is still hot, empty the contents of the flasks into a strainer to recover the oil, which can be used repeatedly. A funnel strainer fitted to the mouth of a 3 or 4 gallon milk can is serviceable and inexpensive.

The funnel strainer mentioned is shown in figure 6. There should be a small quantity of absorbent cotton placed in the bottom of this strainer, so that only the oil can collect in the can beneath.

STOPPERS TO BE USED.

If copper flasks are used, a special No. 5 rubber stopper will have to be made, so as to stand the high temperature. Figure 7 shows the results of the heat on three rubber stoppers when run in a double-walled copper flask. The temperature of the oil in the inner flasks in each of these tests was 190° C. when the flame was extinguished. Stopper A was made especially to stand high temperatures and was tested once; stopper B was also especially made by the same manufacturer who made stopper A, but was tested 30 times, while stopper C is the regular No. 5 stopper and was tested only once. It is important that a special stopper which will stand high temperatures be used if flour and meal are run in the copper flask.

HOW TO TEST DIFFERENT SUBSTANCES.

The methods used in testing flour and corn meal are as follows:

Wheat flour.—Use 150 c. c. of oil both in the inner flask and between the two walls and 50 grams of flour in the inner flask. Extinguish the flame when the temperature reaches 190° C. The oil in the inner flask should reach 190° in about 30 minutes.

Corn meal.—Use 150 c. c. of oil both in the inner flask and between the two walls and 50 grams of corn meal in the inner flask. Extinguish the flame when the temperature reaches 175° C. The oil in the inner flask should reach 175° in about 26 minutes.

TIME OF TEST.

One of the most important factors in getting correct results in the test here described is the time in which it is made. Unless the flame is under the direct control of the operator and run in accordance with the following directions, the test will not be accurate.

The flame should be so adjusted that the temperature of the oil in the inner flask will reach 120° C. in 15 minutes and rise approximately 5 degrees for every minute after that until it reaches the desired temperature. This will require 14 minutes for oil containing flour after it gets to a temperature of 120° to reach a temperature of 190° , and 11 minutes for oil containing meal after it gets to a temperature of 120° to reach a temperature of 175° . If the oil in the inner flask reaches a temperature of

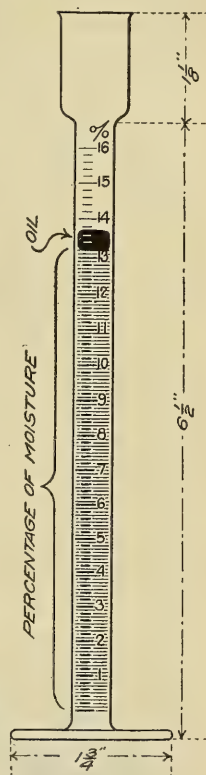


FIG. 4.—Graduated measuring cylinder, showing 13.2 per cent of moisture.



FIG. 5.—Test-tube cleaner.

120° in less than 15 minutes, the flame should be turned down, so that the temperature will rise approximately 5 degrees a minute. If it takes more than 15 minutes to reach 120°, the flame may be turned up, so that the temperature will rise at the rate mentioned. The temperature of the oil in the inner flask should rise from 120° to 150° in approximately 6 minutes. If the oil between the walls is not emptied and another test is made before the oil gets cool, the time required to reach 120° will be less than 15 minutes with a proper flame.

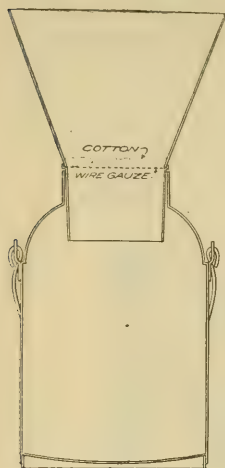


FIG. 6.—Strainer for recovering the oil.

METHOD OF FINDING THE PROPER TEMPERATURE.

The proper temperature at which to extinguish the flame in the apparatus was found by checking duplicate samples in the common type of double-walled water oven that was 11 inches high, 11 inches wide, and 10 inches deep, outside dimensions, and having a 1-inch space between the outer and the inner wall for the water.

The water in the oven was kept boiling by two gas flames and was kept at a uniform height. The different substances were allowed to remain in the oven until they came to a constant weight.

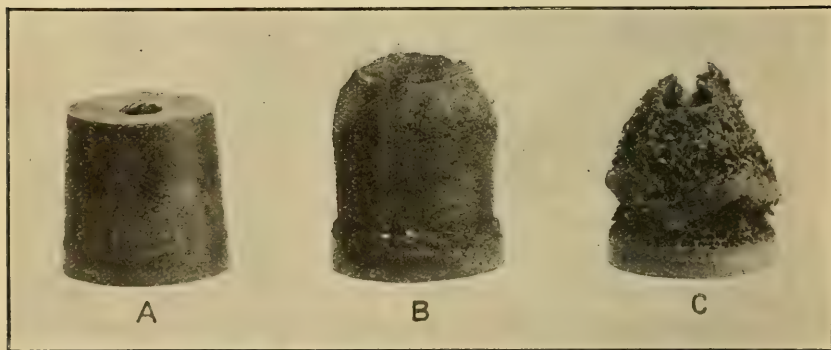


FIG. 7.—Rubber stoppers, showing the effect of heat when tested in a copper flask. Stopper *A* was tested once, *B* 30 times, and *C* once.

POINTS TO REMEMBER.

(1) Both in the inner flask and between the two walls 150 c. c. of oil should be used.

(2) The thermometer in the copper flasks can be easily adjusted by so placing the bulb of the thermometer in flour or meal that a thin coating is left upon it. The thermometer is put into the flask and

quickly withdrawn, so as to see the height of the oil on the thermometer, which should be so adjusted that the bulb will be three-fourths of its length in the oil.

(3) A moderate, steady flame should be kept, which will take 15 minutes for the oil in the inner flask to reach 120° C., 26 minutes for the entire test for corn meal, and 30 minutes for flour. If the oil is hot between the two walls when the test is begun, the time required to reach 120° with a proper flame will be less than 15 minutes. In such instances the time from 120° to 150° C. should be approximately 6 minutes.

(4) The thermometer should rise about 5 degrees C. in 1 minute.

(5) After the flame is extinguished there is an increase of 10 to 15 degrees C. in temperature.

(6) Before taking a reading the distillation flask should be disconnected from the condensing tube and all the moisture allowed to collect in the graduate.

(7) The outside flask can be corked while the inner one is being emptied, and the same oil may be used five or six times before being changed.

(8) Cotton should be placed at the bottom of the funnel strainer.

(9) The inner flask should be rinsed out with an extra 150 c. c. of oil after it is emptied of the corn meal or flour.

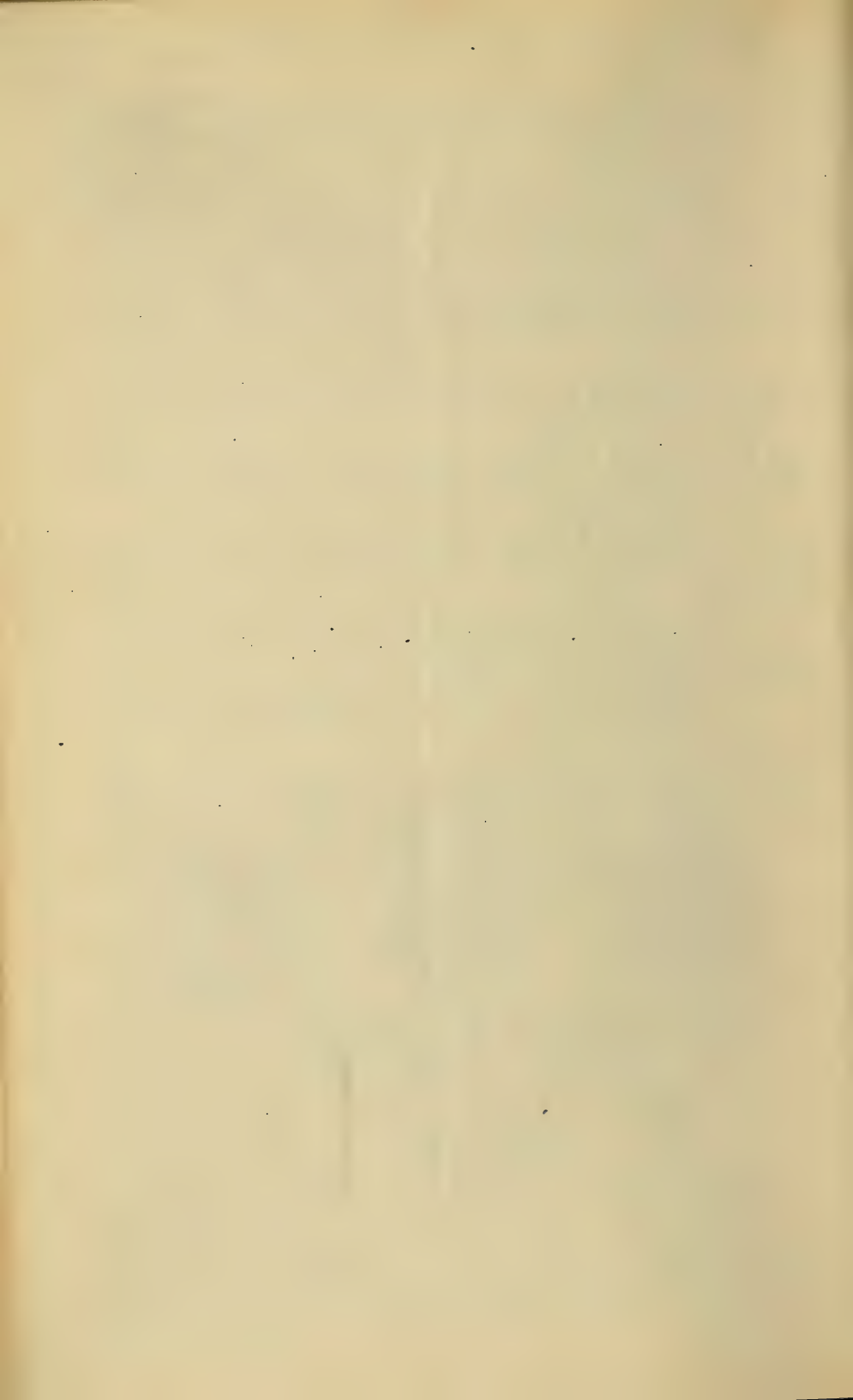
(10) Only special stoppers of the best quality should be used in the necks of the copper flasks.

(11) To insure accurate results when testing flour or meal a special measuring graduate should be used.

(12) For correct results the first run in new flasks should be discarded and the results of the second one taken; also, if the apparatus has not been used for several days, a second run should be made.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



No. 57

Contribution from the Office of Experiment Stations, A. C. True, Director.

February 21, 1914.

WATER SUPPLY, PLUMBING, AND SEWAGE DISPOSAL FOR COUNTRY HOMES.

By ROBERT W. TRULLINGER,
Rural Engineer, Office of Experiment Stations.

INTRODUCTION.

It is the purpose of this paper to treat in a simple manner that portion of the subject of farm home sanitation relating to pure water supplies, the safeguarding of the same against contamination, and the safe disposal of sewage. A few suggestive drawings and illustrations are given to fit average cases, together with information intended to aid the farmer, if necessary, to modify the designs in order to apply them to his particular needs.

The greater part of this work is based on accepted scientific and sanitary principles, and many facts have been drawn from the works of authorities, to whom due acknowledgment is given.

THE FARM WATER SUPPLY.

DANGERS FROM CONTAMINATION.

Without doubt many of the germ diseases may be transmitted by means of water; and some of the diseases are so uniformly transmitted by water that they are known as "water-borne" diseases. Typhoid, dysentery, and other intestinal disorders are such diseases, and if they may be carried by water it is of the greatest importance that every precaution be taken to insure a pure water supply.

Farm water supplies may be divided into three classes, which in the order of their liability to pollution are surface supplies, shallow underground supplies, and deep underground supplies. The surface supplies are obtained from streams, ponds, reservoirs, and cisterns; both shallow and deep underground supplies are obtained from dug, bored, driven, or drilled wells, and from springs.

That farm water supplies are very subject to pollution is evidenced by the investigations of various authorities. The investigations of K. F. Kellerman and H. A. Whitaker,¹ of this department, in coopera-

¹ U. S. Dept. Agr., Bur. Plant Indus. Bul. 154.

tion with the Minnesota State Board of Health, indicate that of 79 carefully selected and typical water supplies in Minnesota 20 were good and 59 were polluted. Of the polluted wells 11 were so located that even extreme care would not make them safe; 10 were poorly located, but improvements in the protection from surface wash and infiltration would make them safe; 25 were bad only because of poor surface protection and could easily be made safe. Practically all the surface supplies investigated were polluted. During these investigations 23 of the farms examined showed a record of typhoid fever.

F. T. Shutt,¹ of the Canada Experimental Farms at Ottawa, reviewing his study of the subject since 1887, states that of the farm water supplies examined 30 per cent may be classified as safe and wholesome, 25 per cent as suspicious and probably contaminated, 36 per cent as seriously polluted, and 9 per cent as nonpotable through high salinity.

SURFACE SUPPLIES.

CONTAMINATION.

Surface water supplies are those most liable to pollution, and authorities agree that they are the most unsatisfactory for farm use. Streams and ponds receive the greater part of the surface wash from the immediate neighborhood, and in many cases barnyard or stockyard drainage from points remote from where the water is taken for household use. Streams or ponds located in pastures, manured fields, or where stock can gain access to them are polluted. Sometimes sewage and house drainage are emptied into streams and ponds. In fact, since they are open and unprotected, there are a thousand and one different sources of pollution for such supplies. Rain waters from the roof are polluted by dust, dirt, and leaves, which collect in the eaves trough, and by the droppings from birds.

Surface water supplies should therefore not be used for household purposes, not even for washing milk cans or for laundry purposes, unless no other supply is available. And it may be safely assumed that the person who drinks water from surface supplies endangers his health if such supplies are not first protected from the sources of contamination as far as possible and then purified.

CISTERNS.

In localities where underground waters are hard to obtain, cisterns may be used for the filtration, partial purification, and storage of rain water, and surface supplies. The size of the cistern will depend on the number of persons in the house and on the general water consumption, as discussed hereafter, under "Pumping, storage, and distribution."

¹ Reprint from Pub. Health Jour., State Med. and Sanit. Rev., 1912, April.

The cistern should be of water-tight construction, to prevent leakage and to prevent pollution from the neighboring soil. It should have an overflow drain and a tight cover. There should also be suitable provision for straining or filtering the water previous to its entrance to the cistern.

The cistern should ordinarily be in two compartments, with a filter wall of porous brick between. One compartment serves then as a settling chamber and the water receives a final filtration before entering the storage compartment.

Concrete is probably the most sanitary and durable material for cisterns. In general, the walls and floor should be 6 or 8 inches thick and well reinforced and the concrete should be carefully proportioned

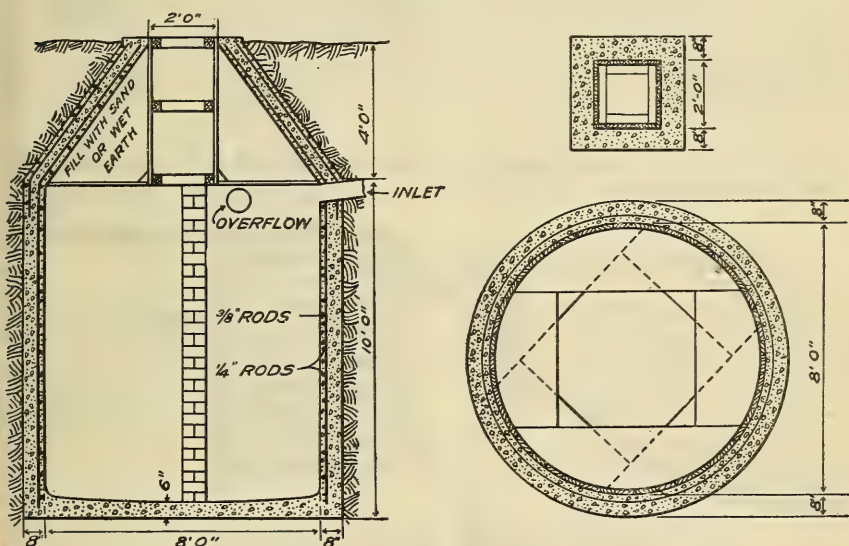


FIG. 1.—Reinforced concrete cistern, showing arrangement of forms and reinforcing.

and mixed. A mixture of 1 part cement to 2 or $2\frac{1}{2}$ parts of clean sharp sand and 4 or 5 parts of clean and fairly small crushed rock or gravel is satisfactory for fairly water-tight concrete. The inside surface should be coated with a 1 to 2 cement mortar. Figure 1 shows a circular cistern of average size sufficient for a family of 6 or 8 people.

In constructing such a cistern, make a circular excavation 16 inches wider than the desired diameter of the cistern and about 16 inches deeper than the desired depth. Make a cylindrical form as shown in the figure, the outside diameter of which will be the inside diameter of the cistern. Mix the concrete in small batches fairly wet and tamp in between the form and the earth. To construct the conical portion, build a floor across the top of the cylindrical form, leaving a hole of the desired size in the center. Brace the floor well with up-rights from the cistern bottom. Build a cone-shaped mold of wet

earth or sand and lay the concrete and reenforcing on this cone. Allow it to set and harden well before removing the forms and earth. The following table gives an approximate bill of materials for two sizes of cisterns:

Cisterns—Material.

[Concrete: 1 part cement, 2½ parts sand, 5 parts gravel.]

Material.	14 feet deep (10-foot cylinder, 4-foot cone), 8 feet in diameter, capacity 3,800 gallons.	13½ feet deep (10-foot cylinder, 3½-foot cone), 6 feet in diameter, capacity 2,100 gallons.
Cement.....bags.....	43	31
Sand.....cubic yards.....	4½	3
Gravel.....do.....	9	6½
Brick for filter wall.....	1,000	800
Lumber for forms.....board feet.....	225	200

The Office of Public Roads of this department has established a method of making concrete by intermixing mineral residuum oil,

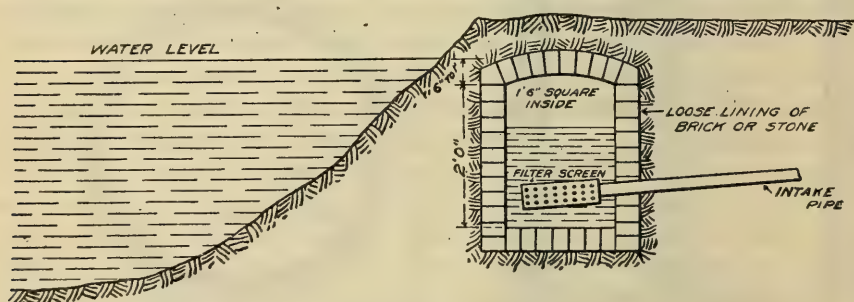
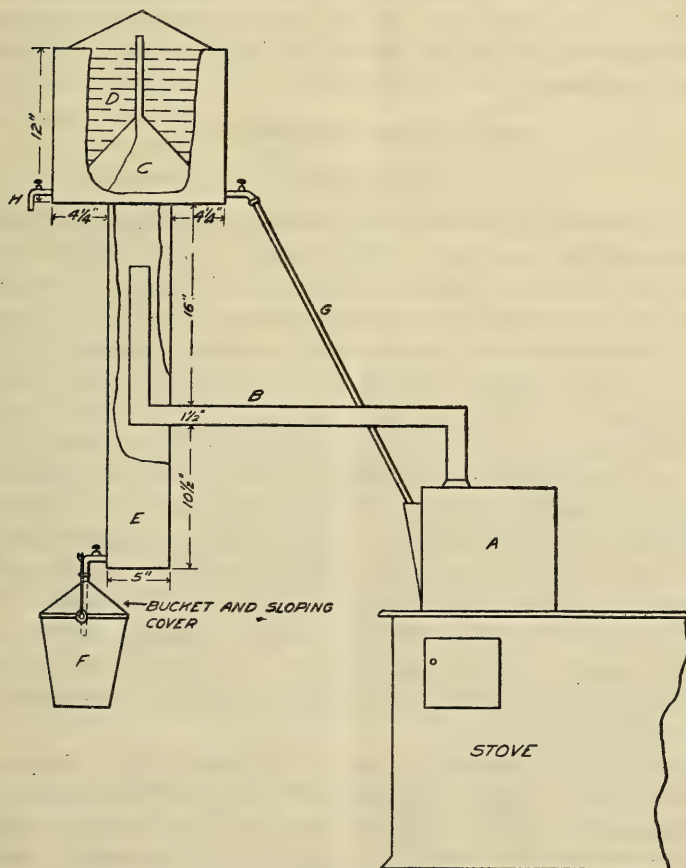
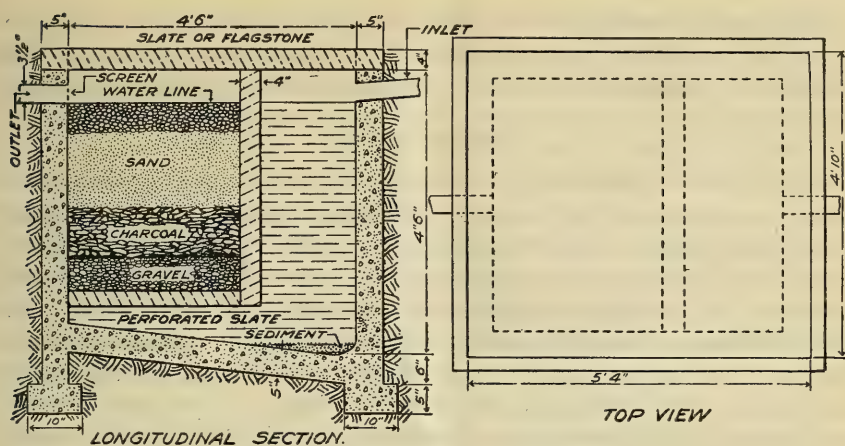


FIG. 2.—Crib of brick or stone for intake from pond.

which, according to their tests, makes a damp-proof and fairly water-tight concrete. Information may be obtained by writing to that office for their bulletin on oil-mixed Portland cement concrete.¹

If water is piped from a stream or pond subject to pollution, the pipe entrance should be placed in a crib and screened, as shown in figure 2. The pipe can then empty into a receiving filter, made of concrete, which contains fine sand, gravel, and powdered charcoal in layers (fig. 3), and from which it empties into the cistern. The rain-water pipe from the eave trough should be provided with a switch or cut-off, so that the flow may be diverted to the outside—as, for instance, for a short time at the beginning of rains—to exclude the filth collected on the roof and gutters. An overflow pipe should be provided in the side of the cistern and should be screened to exclude rats and other vermin.

¹ U. S. Dept. Agr., Office Pub. Roads Bul. 46.



The above treatment will, in a large measure, purify surface water for household uses other than drinking or cooking; but if this water is to be used for drinking or cooking it should first be boiled.

DISTILLED WATER.

Sometimes a simple still can be conveniently used on a kitchen range to provide distilled water for drinking purposes. Saline (alkali) waters are satisfactorily treated in this way. Figure 4 illustrates a form of still which has been found effective and convenient for household use.¹ It has the advantage of being inexpensive and can be made by any tinner. The still consists essentially of a water boiler (*A*) on the range, having a capacity of about 1½ to 2 gallons, and a condenser suspended at the proper height from the ceiling. The pipe (*B*) conveys steam to the condensing chamber (*C*) and is kept cool by water in the compartment (*D*). The distilled water collects in (*E*) and can be drawn off from time to time or allowed to run continuously into the bucket (*F*). The metal used in the construction of the still should be well-tinned copper and no solder should be exposed to the action of either the steam or the distilled water.

UNDERGROUND WATER SUPPLIES.

CONTAMINATION.

It is usual to distinguish between shallow underground supplies and deep underground supplies. Wells from 15 to 30 feet in depth to water flowing in a layer of gravel or sand, which rests on an impervious stratum, are considered as sources of shallow underground supply.

Both shallow and deep farm wells are often polluted from local sources. They are often located for convenience in the barnyard, under the barn or stable, close to stock pens, privy vaults, or leaching cesspools, or close to the back door, out of which household slops are thrown and near which animal and vegetable refuse is often allowed to accumulate and decompose. The soil surrounding the well becomes saturated with organic filth and, unable finally to perform its useful work of filtration and purification, allows the surface water percolating through it to carry its load of contamination into the well.

The curbing or covering is often loosely constructed of boards, permitting small animals and vermin to fall into the well; and surface water carrying filth and manure, especially after rains, runs into the well from the top.

The well may be located at such a distance from sources of contamination that ordinary pumping will bring no bad results, but in case of unusually heavy pumping the underground water surface for a distance around the well may be sufficiently lowered to reach the zone of contamination. This principle is illustrated in figure 5.

¹ Montana Sta. Circ. 7.

Deep bored or driven wells are less liable to pollution than shallow dug or bored wells, since in the first case the wells are usually imperviously cased and the surface water must filter through a depth of soil equal to the depth of the well before gaining access to it, while in the second case the wells are usually loosely lined with brick or stone, and the surface water, having only a short distance to filter, seeps in through the entire depth.

That both deep and shallow wells are subject to contamination is shown from many examinations which have been made. Of 177 deep and 411 shallow farm wells examined in Indiana,¹ 116 of the deep well waters were of good quality, 45 were bad, and 16 were doubtful; 159 of the shallow well waters were good, 209 were very bad, and 43 were doubtful.

The safety of water supplies when near sources of possible surface pollution often depends largely on the character and quality of the material in which the well is sunk. Surface waters in sinking through sandy soils or surfaces are filtered, and in the finer sands much of the polluting matter which they carry is frequently removed. In coarser sands or gravel the degree of filtration is less, but water taken from sands and gravels at a considerable depth may be considered relatively safe. Waters from wells in clay are not often polluted, since surface pollution filters through clay very slowly.

Waters from wells in limestone are frequently polluted, owing to the fact that limestone soils usually contain passages and channels at different depths which sometimes form a continuous passage for underground water for a considerable distance and which are very often directly connected with sinks and basins occurring here and there on the surface. It is a common practice to dump manure, trash, and garbage into such sinks or basins, and rain water falling into these plunges directly into the underground channels, carrying with it the impurities from the basin to those points where wells are sunk. In this manner garbage or refuse dumped anywhere in the neighborhood of or even at a considerable distance from a well in limestone may pollute the water. Figure 6 shows how the pollution of wells and springs may occur in limestone.

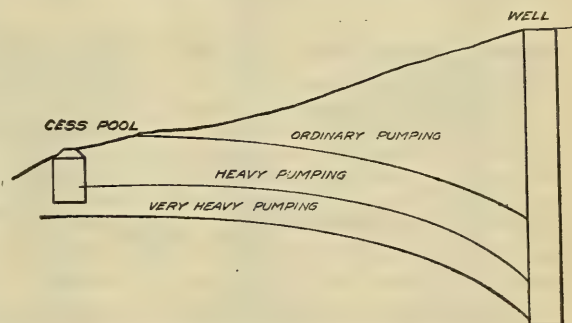


FIG. 5.—Effect of pumping on ground water.

¹ Ann. Rpts. Ind. Bd. Health, 27 (1908), p. 345; 29 (1910), p. 349.

Deep wells in granite or jointed rock are often polluted, although cased to a great depth, since polluted water may sink in a zigzag course along the rock joints until it reaches the bottom of the well casing. It is therefore necessary to exercise care in the location of the well and in the preliminary protection from pollution.

WELL LOCATION AND PRELIMINARY PROTECTION.

The farm well, especially a shallow dug well, should be located somewhat above the barns, buildings, yards, and stock pens, or at least in such a position that the surface drainage from all possible sources of animal and vegetable contamination is away from the well. The location should also be as far removed from these sources as convenience will permit.

To properly safeguard wells against outside contamination, first, all sources of contamination should be removed as far as possible. If local conditions and prices will permit, it is a good idea to provide

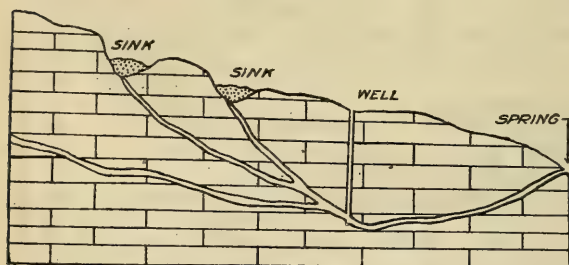


FIG. 6.—Pollution of subsurface water in limestone.

impervious floors with water-tight drains for farm buildings and stock pens.¹ Under the same conditions concrete manure pits might well be provided to not only prevent the liquid manure from polluting the neighboring soil

but to save the manure. No garbage, manure, or rubbish should be dumped into sinks or basins in the immediate neighborhood, and these should be fenced off and kept free from polluting matter. The house should be provided with some safe method of sewage disposal, while slops and garbage from the kitchen should be deposited in tightly covered garbage cans and disposed of by burying in the fields, burning, or feeding to pigs. The use of privy vaults and leaching or overflowing cesspools should be absolutely avoided, since they are likely to be sources of the worst contamination. Second, the farmer should become acquainted with the various types of wells and the best methods of protection, and the well should be so protected as to exclude filth from those sources of contamination which it has been impossible to remove or have been overlooked.

TYPES OF WELLS AND METHODS OF SINKING.

In the selection, location, and sinking of a well it is always a good idea to consider permanence in addition to safety. This will depend on the kind of well used, and one should be acquainted with well

¹ U. S. Dept. Agr., Farmers' Bul. 481.

types and methods of sinking. The well should penetrate to levels below that of the ground-water surface in the driest seasons.

Figure 7 illustrates four different common types of deep and shallow wells. No. 1 shows a dug well, with pump, which may be lined with either concrete or cemented brick. No. 2 shows a driven well, which is constructed by attaching a point on the end of the pipe and driving the pipe into the ground until water is reached. The point is provided with a short length of pipe with perforations which permit the water to enter the pipe and keeps out the sand and gravel. This arrangement is best suited to shallow wells, as the cylinder is near the surface in a dry well. If the depth to water is greater than the suction limit, it is necessary to dig a dry well deep enough to place

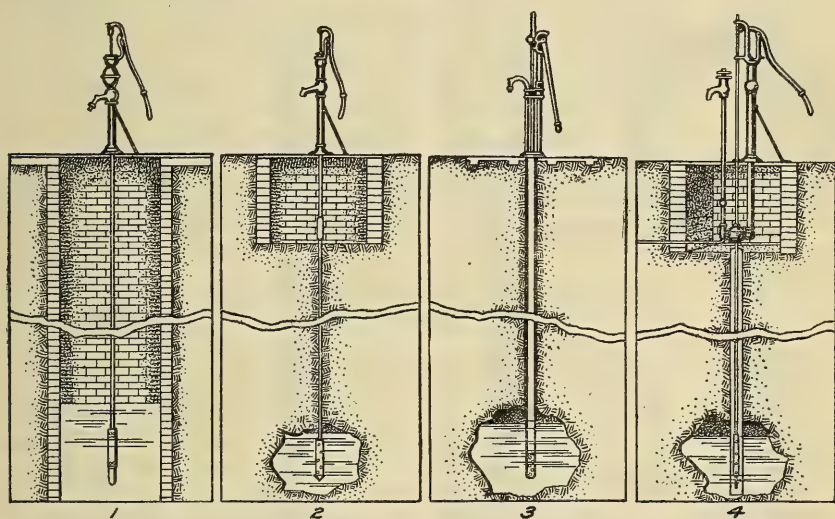


FIG. 7.—Types of deep and shallow wells.

the cylinder within the suction limit. Nos. 3 and 4 are drilled wells consisting of a small hole which may be from 3 inches to 15 inches in diameter. This hole is lined with an impervious iron casing which prevents caving in and keeps out all water, except that which enters at the bottom. This type of well can pass through as many water-bearing beds as desired and none but that from the lowest will enter. The casing is large enough to allow the cylinder to be placed below the water surface, or as near the water as is necessary. No. 4 shows a drilled well with a dry well installed above it to accommodate the lower half of a pump made for underground discharge.

M. L. Fuller¹ states in regard to types of shallow wells and conditions to which they are adapted:

Dug wells are generally circular excavations 3 to 6 feet in diameter. They are adapted to localities where the water is near the surface, especially where it occurs

¹ M. L. Fuller. *Domestic Water Supplies for the Farm*. New York and London, 1912, p. 68.

in small seeps in clayey materials, and requires extensive storage space for its conservation. Bored wells are wells bored with various types of augers from 2 inches to 3 feet in diameter rotated or lifted by hand or horsepower. They are usually lined with cement or tile sections with cemented joints and often with iron tubing. They are adapted to localities where the water is at slight or medium depths and to materials similar to those in which open wells are sunk. Punched wells are small holes usually less than 6 inches in diameter sunk by hand or horsepower by dropping a steel cylinder slit at the side so as to haul and lift material by its spring. They are adapted to clayey material in which water occurs as seeps within 50 feet of the surface, but not at much greater depths. These wells should also be lined with tile, iron tubing, or sheet-iron casing. Driven wells are sunk by driving downward, by hand or horsepower apparatus, small iron tubes, usually $1\frac{1}{4}$ to 4 inches in diameter, and provided with point and screen. They are adapted to soft and fine materials, especially to sand and similar porous materials, carrying considerable water at relatively slight depths, and

are particularly desirable where the upper soil is likely to be polluted.

Since most well-water supplies are obtained from sand and fine gravels, the cheapest and best method of well sinking is by driving. In a driven well the water can only be polluted at the depth of the strainer. In some materials, such as clay, it is necessary to bore the well, in which case it is absolutely necessary for safety

that the well be lined with impervious casing to the strainer. Deep and shallow dug wells should also be lined.

PROTECTIVE WELL LININGS.

For lining shallow dug wells the latest practice has been the use of reenforced concrete. This has also been successfully practiced in lining deep dug wells. Concrete may be made practically impervious to water, so that a concrete-lined shallow or deep dug well can only be polluted from the bottom.

Figure 8¹ suggests a method of lining dug wells with concrete. Dug wells are usually about 6 feet in diameter. The concrete need be only about 6 inches thick with vertical steel reenforcing of $\frac{3}{8}$ -inch rods spaced 18 inches apart, and circular reenforcing of $\frac{1}{4}$ -inch steel

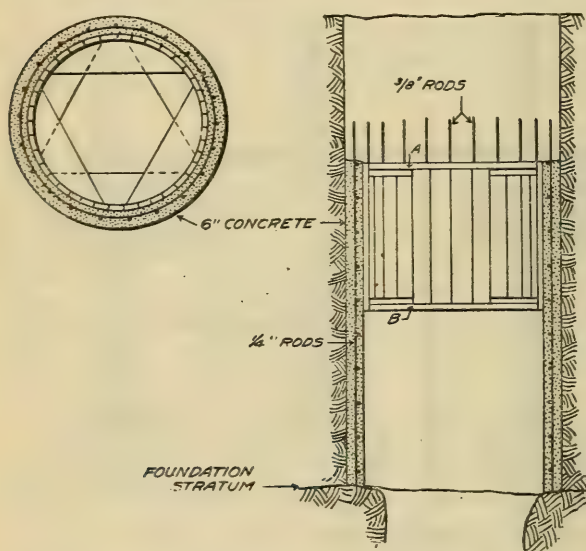


FIG. 8.—Concrete well lining, showing arrangement of forms.

¹ F. N. Taylor. *Small Water Supplies*. London [1912], pp. 34-36.

rods spaced about 9 inches. The two sets should be bound together by steel wire with the circular reenforcing placed inside the vertical. A carefully proportioned concrete mixture of 1 part cement and 2 parts sand to 4 parts of gravel or crushed rock should be used. A circular collapsible form is necessary, with diameter 12 inches less than the diameter of the well and about 5 feet long. The two rings, *A* and *B*, are cut to a diameter equal to that of the shaft, less twice the thickness of the concrete and 4 inches for the 2-inch lining boards. The rings are made by drawing a circle the size of the frame and laying boards around its circumference, as shown by the figure. The boards are then lightly tacked together and a circle of the same radius marked on three ends. Finally, around the circumference of the ring are fastened boards, each 2 inches thick and of the required length of the form. The concrete lining rests on the bottom of the well, which has been previously leveled to receive it. A wet mixture is advisable for this class of work. The form should be left in until the concrete has properly set before it is raised to construct the next section.

In regard to other types of well lining or casing M. L. Fuller¹ says:

Cemented rock or brick linings protect the well from pollution, except at the bottom, as long as the walls are not cracked. They also prevent the entrance of sediments and animals and do not impart a taste to the water. Iron casings are used in both rock and unconsolidated materials. They are usually used in deep wells. They may be either iron tubing 1 to 4 inches in diameter, or sheet-iron casings 4 to 16 inches in diameter, with snug joints. They are adapted to wells of all depths in which water is obtained from a stratum below the casing or from a stratum between cased sections, or in case it is decided to procure water from a number of strata.

Iron casings may be obtained from manufacturers of pumping apparatus or from hardware dealers. Figure 9 shows a type of iron casing with pump inside.

PROTECTIVE WELL CURBINGS OR COVERINGS.

Both shallow and deep wells should have water-tight curbs, in addition to impervious casings. The drip from the pump is often the cause of serious pollution. The casing or lining should extend 6 or 8 inches above the ground surface except when a dry well is used, and a concrete curbing should be built over the top with a slope away from the pump opening in the center. This cover should extend at least 2 feet beyond the edge of the well if a dug well, and if a bored or driven well the cover should extend 4 to 6 feet in all

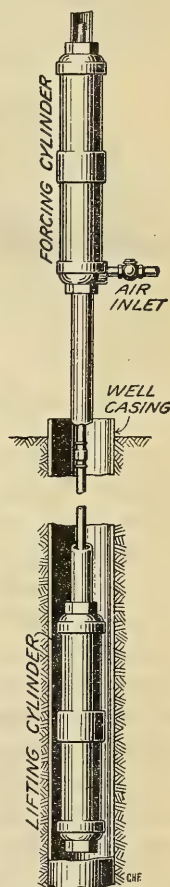


FIG. 9.—Iron well casing with pump and cylinder inside.

¹ M. L. Fuller. Domestic Water Supplies for the Farm. New York and London, 1912, p. 70.

directions from the center. The outer edge should be raised to form a trough emptying into a tight drain, or a drain trough should be provided to catch the drip. E. Bartow¹ suggests that the earth be excavated for 4 feet outside of the regular casing to a depth of 4 feet and that an extra 4-inch coating of waterproof Portland cement mortar be placed outside this casing with 4 to 6 inches of mortar in the bottom of the excavation. This bottom should have a raised portion at its outer edge to divert the seepage water to a tile drain. This arrangement prevents surface water that has not been filtered through at least 4 feet

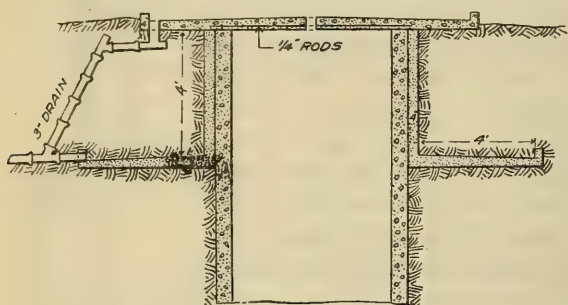


FIG. 10.—Well protection.

of earth from gaining access to the well. Figure 10 shows a combination of these protective arrangements.

SPRINGS.

Springs are good sources of water supply, since they usually come from great

depths within rock or are filtered through many layers of sand and gravel. However, they are subject to pollution from the same sources as wells and should be closely watched in this respect. Farm spring supplies are often polluted by the drainage from buildings and stock pens. Spring water supplies from limestone are also subject to pollution from distant garbage and sewage dumps in sink holes, as shown in figure 6. The same precautions should be taken for safeguarding spring supplies as in the case of wells, and in addition the spring should always be fenced to keep out

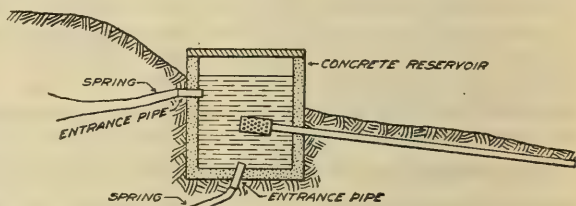


FIG. 11.—Method of walling in springs.

stock. It should be cleaned of all trash and walled in to form a kind of reservoir, as shown in figure 11. The supply may then be conducted to the house by gravity or by means of a hydraulic ram. Where a spring is small a large vitrified tile may be so placed as to form a small storage reservoir. The reservoir should be covered and protected as much as possible from filth and vermin. After rains the spring should be noticed for any signs of turbidity which may indicate pollution from

¹ Univ. Ill. Bul., 7 (1909), No. 2.

distant surface sources. Spring supplies should be frequently examined for pollution of any kind, and the water should be boiled before drinking, if possible, although this is not absolutely necessary in all cases.

PUMPING, STORAGE, AND DISTRIBUTION OF WATER.

After a pure water supply is made available the first things to be considered are the quantity of water needed, choice of pumping equipment, and means of storage and distribution.

QUANTITY OF WATER NEEDED.

The quantity of water needed depends on the power used and whether the service is for the entire farm or for the house only. Hand-operated systems are applicable where small quantities are required for house service only, but in case water is wanted for stock also the use of a windmill, engine, electric motor, or hydraulic ram is necessary. If a windmill is used the storage should be large enough for at least three days' supply, to provide water in case of calm weather. Where the other sources of power are used the storage capacity need not exceed one day's supply. The following table gives approximate quantities of water required per day:

Approximate quantities of water required per day.

	Gallons.
Each member of the family for all purposes will require.....	25-40
Each cow will require.....	12
Each horse will require.....	10
Each hog will require.....	2½
Each sheep will require.....	2

The water consumption will vary from day to day and with the seasons. Fire protection should also be considered, and in determining the size of tank the maximum amount likely to be required should be provided.

For a family of 6 persons a 200-gallon supply should be sufficient if the water is used in the house only. On a farm where water is supplied to a family of 6 persons, 10 horses, 12 cows, 25 hogs, and 15 sheep, the daily storage supply should be at least 500 gallons, with whatever additional amount, if any, the farmer deems necessary for fire protection.

There are three general systems of storage and distribution which may be readily applied to farm conditions, viz, the gravity, pneumatic, and autopneumatic systems.

THE GRAVITY SYSTEM.

In the gravity system water is forced into an elevated tank placed higher than the highest discharge cock. A storage tank may be placed in the attic, on the roof, or on a tower outside. The agricultural experiment station at Ames, Iowa, has designed a silo with the storage tank placed on top. Figure 12 shows a gravity system with the stor-

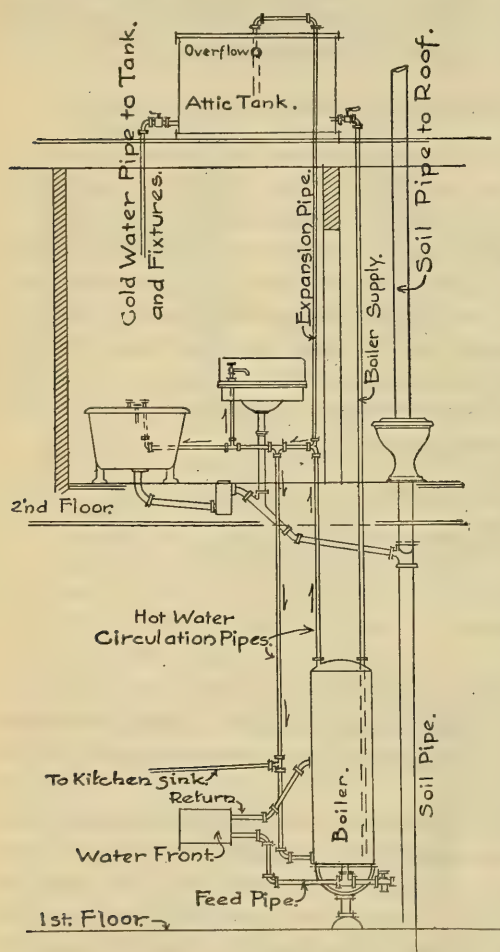


FIG. 12.—Gravity supply system with storage tank in attic.

age tank in the attic and figure 13 (p. 16) shows the storage tank placed on the windmill tower. Since there is considerable frictional resistance to the flow of water through the distribution pipes, the tank should be placed at least 10 feet higher than the highest discharge cock to insure a flow under pressure. Water weighs 62.5 pounds per cubic foot, or about 8.4 pounds per gallon, so that in placing a tank in the attic or on the roof the supports should be made sufficiently strong to uphold this weight. Either wooden or galvanized metal tanks may be used. Wooden tanks may be obtained of almost any size, either circular or rectangular in shape. They are generally built of cedar or cypress, and are slightly conical. They are usually knocked down

when shipped, and should be set up and filled with water as soon as received. The foundation should be good and solid and the weight of the tank should rest on the tank bottom and not on that part of the stave which projects below. The capacities of circular tanks may be found by the following: Capacity in gallons equals diameter in feet, squared, multiplied by 0.7854, multiplied by the depth in feet, multiplied by 7.48. One cubic foot equals 7.48 gallons. When located in buildings wooden tanks are commonly made rectangular.

They may be lined with tinned copper, but never with lead. To obviate the use of heavy planking, rods are used to rigidly tie together the end and side braces.

Steel tanks may be purchased in circular, round end oblong, and rectangular shapes. Commercial sizes of these tanks are given in the following tables:

Round storage tanks.

Diameter.	Height.	Capacity.	Diameter.	Height.	Capacity.
<i>Feet.</i>	<i>Feet.</i>	<i>Gallons.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Gallons.</i>
3	2	106	5	3	440
4	2	189	5	4	588
4	2½	235	5	5	735
4	3	283	5	6	880
4	4	378	5½	8	1,400
4	5	470	6	2	423
4	6	567	6	2½	528
4	8	756	6	3	635
5	2	299	6	4	845
5	2½	368	6	5	1,056

Round end storage tanks.

Width.	Height.	Length.	Capacity.	Width.	Height.	Length.	Capacity.
<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Gallons.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Gallons.</i>
2	2	4	118	4	2	14	820
2	2	5	150	4	2	16	945
2	2	6	181	4	2½	8	536
2	2	7	202	4	2½	10	756
2	2	8	236	4	2½	16	1,200
2	2	10	299	4	3	8	725
2	2½	8	299	4	3	10	915
2½	2	8	299	4	5	10	1,480
2½	2	10	378	5	2	16	1,200
2½	2½	8	378	5	2½	16	1,480
3	2	8	362	6	2	8	740
3	2	10	440	6	2	10	900
3	2½	8	440	6	2	16	1,420
3	2½	10	567	6	2½	8	900
3	3	10	662	6	2½	10	1,120
4	2	8	473	6	3	10	1,340
4	2	10	598	6	4	10	1,760
4	2	12	693	6	5	10	2,200

Tanks 4 feet long, 1 top brace; 5, 6, and 7 feet, 1 side and 1 top brace; 8 feet, 2 side and 1 top brace; 10 feet, 3 side and 2 top braces; 16 feet, 5 side and 3 top braces.

Square end storage tanks.

Width.	Height.	Length.	Capacity.	Width.	Height.	Length.	Capacity.
<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Gallons.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Gallons.</i>
2	2	4	118	3	2	10	448
2	2	5	150	3	2½	8	448
2	2	6	181	3	2½	10	565
2	2	7	210	3	3	10	673
2	2	8	240	4	2	8	478
2	2½	8	299	4	2	10	598
2½	2	8	299	4	2½	8	598
2½	2½	8	378	4	2½	10	748
3	2	8	360	4	3	8	718

Tanks 4, 5, and 6 feet long, 1 side and 1 top brace; 7 and 8 feet, 2 side, 1 top brace; 10 feet, 3 side, 2 top braces; longer and deeper tanks are extra well braced.

THE PNEUMATIC TANK SYSTEM.

The pneumatic tank system consists of a force pump, an air-tight steel tank, necessary pipe, valves, fittings, etc., and power for operating the pump. The system may be a small one operated by hand, windmill, or small engine, or it may consist of a large pump operated by a powerful engine with two or more tanks of large capacity. The tank may be placed in the basement or underground, thus keeping the water cool and preventing freezing. Figure 14 shows a pneumatic system with the tank in the basement and supplied by a hand force pump. This figure also well illustrates the water plumbing. Figure 15 shows the tank in the basement supplied by a windmill deep-well pumping outfit. The tank may be set in the ground below frost line close to the well or house foundation.

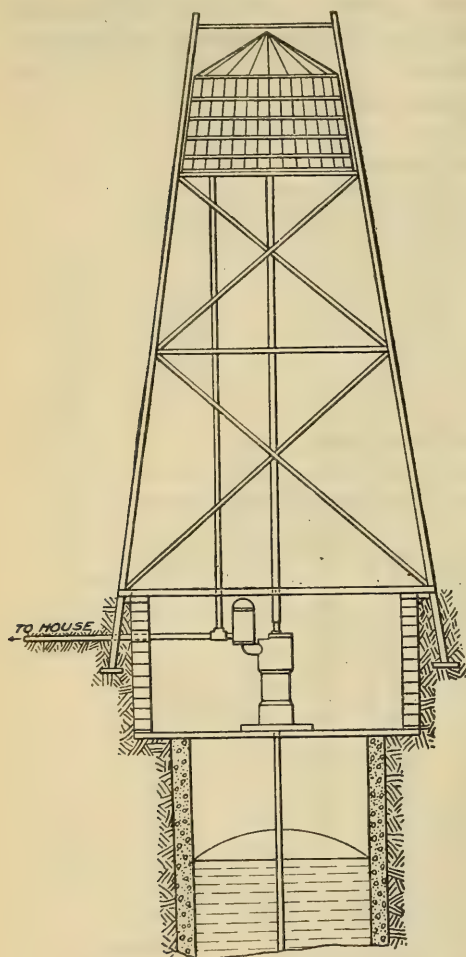


FIG. 13.—Gravity supply system with storage tank on windmill tower.

the computed storage capacity be added to provide space for the compressed air. The following table gives commercial sizes of pneumatic tanks:

In the operation of the pneumatic system water is forced into the air-tight tank, thus compressing the air into a smaller space and creating an air pressure which forces the water to the discharge cocks. In determining the capacity of the tank, then, it is necessary that about one-third of

Commercial sizes of pneumatic tanks.

Diameter.	Length.	Weight.	Capacity.	Diameter.	Length.	Weight.	Capacity.
Inches.	Feet.	Pounds.	Gallons.	Inches.	Feet.	Pounds.	Gallons.
24	6	445	140	42	10	1,650	720
24	8	560	195	42	12	1,900	865
24	10	675	245	42	14	2,200	1,000
30	6	560	220	42	16	2,400	1,150
30	8	700	295	48	10	2,066	1,000
30	10	870	365	48	12	2,320	1,130
30	12	900	440	48	14	2,610	1,300
36	6	750	315	48	16	2,900	1,500
36	8	900	420	48	18	3,600	1,700
36	10	1,050	525	48	20	3,950	1,880
36	12	1,200	630	48	24	4,650	2,260
42	8	1,450	575	60	20	5,900	2,940

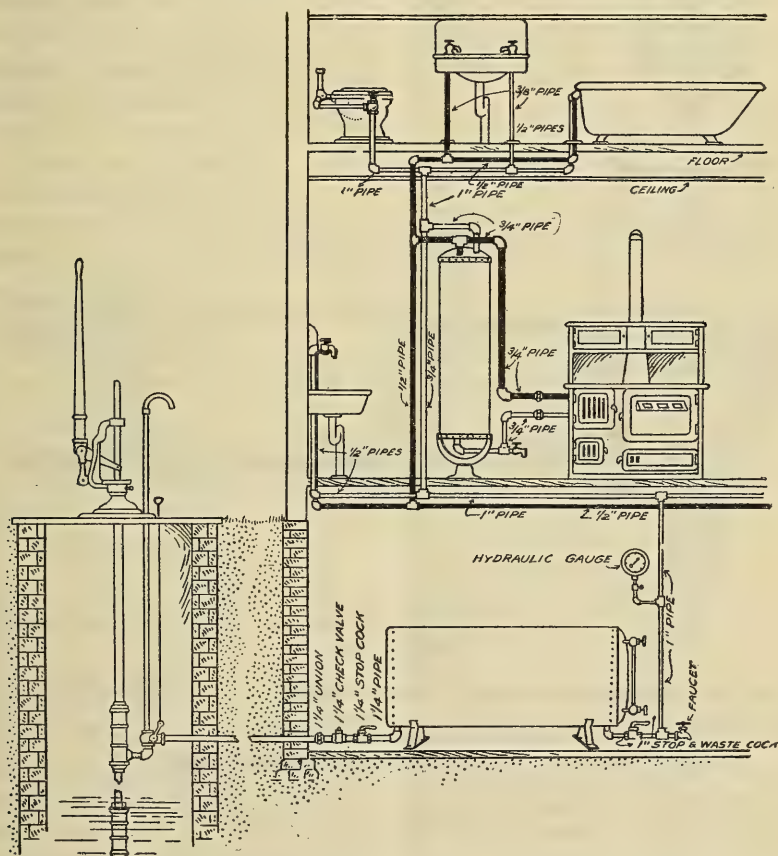


FIG. 14.—Pneumatic tank supply system with tank in basement supplied by hand force pump.

Each tank is equipped with a pressure gauge which will show the internal pressure at any time. If water is pumped into the tank until the pressure gauge registers 25 pounds, water can be forced about 60 feet above the tank. If a discharge cock 20 feet above the tank is opened, water is discharged until the pressure falls to 8.6

pounds, when it is insufficient to deliver the remaining water 20 feet high. It will also be found that when air is compressed in the same tank with water, the water gradually absorbs the air, thus making constant renewal of the air necessary. Both of the above troubles are overcome by compressing excess air in with the water until the pressure gauge again registers 25 pounds, if the tank is half full of water. Excess air pressure may be secured by an air intake valve in the suction pipe, controlled by hand, by a combination of air and water pump, or by use of an air compressor when power is used.

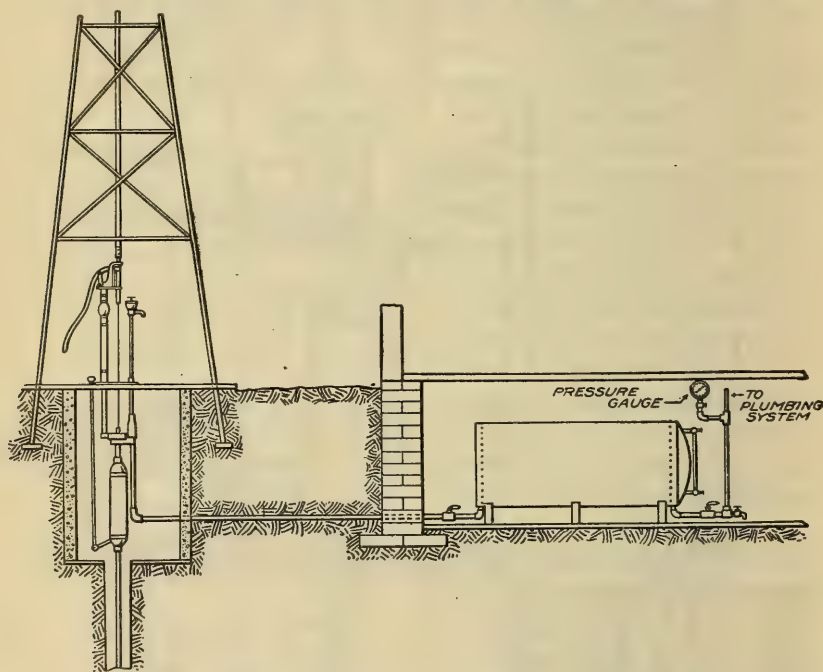


FIG. 15.—Pneumatic tank supply system with tank in basement supplied by windmill deep-well pumping outfit.

The following table gives the pressures in the tank necessary to force water to certain heights in the house:

Feet head of water and equivalent pressure in tank.

Elevation.	Pressure in tank.	Elevation.	Pressure in tank.	Elevation.	Pressure in tank.
<i>Feet.</i>	<i>Pounds.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Feet.</i>	<i>Pounds.</i>
1	0.43	20	8.66	75	32.48
2	.87	25	10.83	80	34.65
3	1.30	30	12.99	85	36.81
4	1.73	35	15.16	90	38.98
5	2.17	40	17.32	95	41.14
6	2.60	45	19.49	100	43.31
7	3.03	50	21.55	110	47.64
8	3.40	55	23.82	120	51.97
9	3.90	60	25.99	130	56.30
10	4.33	65	28.15	140	60.63
15	6.50	70	30.32	150	64.96

Pipe friction should be included in computing the pumping height, as discussed under "Pumping."

THE AUTOPNEUMATIC SYSTEM.

In the autopneumatic system the water is delivered fresh from the well to the faucets. This system consists essentially of an air compressor driven by a small gas engine or electric motor, an air-tight steel air-pressure tank, and one or more autopneumatic pumps. No water tank is required, since nothing is stored but compressed air. The pump consists of two small metallic chambers submerged in the water, and when a faucet is opened they automatically fill and discharge, owing to the air pressure from the storage tank, thus giving a continuous flow of fresh water.

Figure 16 illustrates the principle of operation of the pump. Suppose a small air-tight tank *A* with inlet valve is submerged in water and allowed to fill. A discharge pipe *B* is connected at the bottom leading upward to faucet *K*. Compressed air is forced through pipe *C* into the top of the tank so that the water is forced out through the discharge pipe until the tank is emptied of water. A similar tank *D* is connected as shown. The pump has a device for automatically opening and closing the air valves and exhaust valves to the tanks alternately. While *A* is emptying of water *D* is filling, and they discharge alternately.

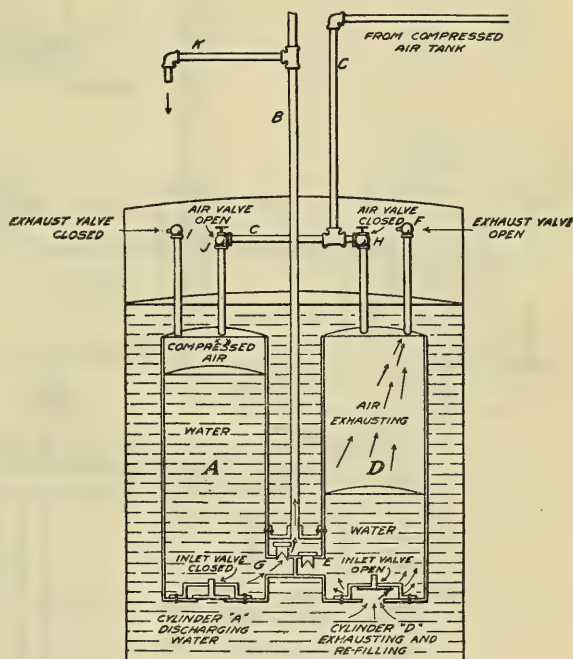


FIG. 16.—Principle of operation of an autopneumatic pump.

Figure 17*A* gives a front and side view of an autopneumatic pump and figure 17*B* shows the entire working parts of a system and also how the pump may be used in bored and cased wells.

Each pump requires an air-pressure reducer, shut-off and release cocks, pressure gauge, etc. The air-pressure reducer is necessary to reduce the high pressure carried in the tank to the uniform low pressure required to operate the pump. It is placed in the air-pipe line

between the air tank and the pneumatic pump. It can be adjusted to the proper pressure with an ordinary wrench. The proper working pressure required to operate the pump and raise water to the

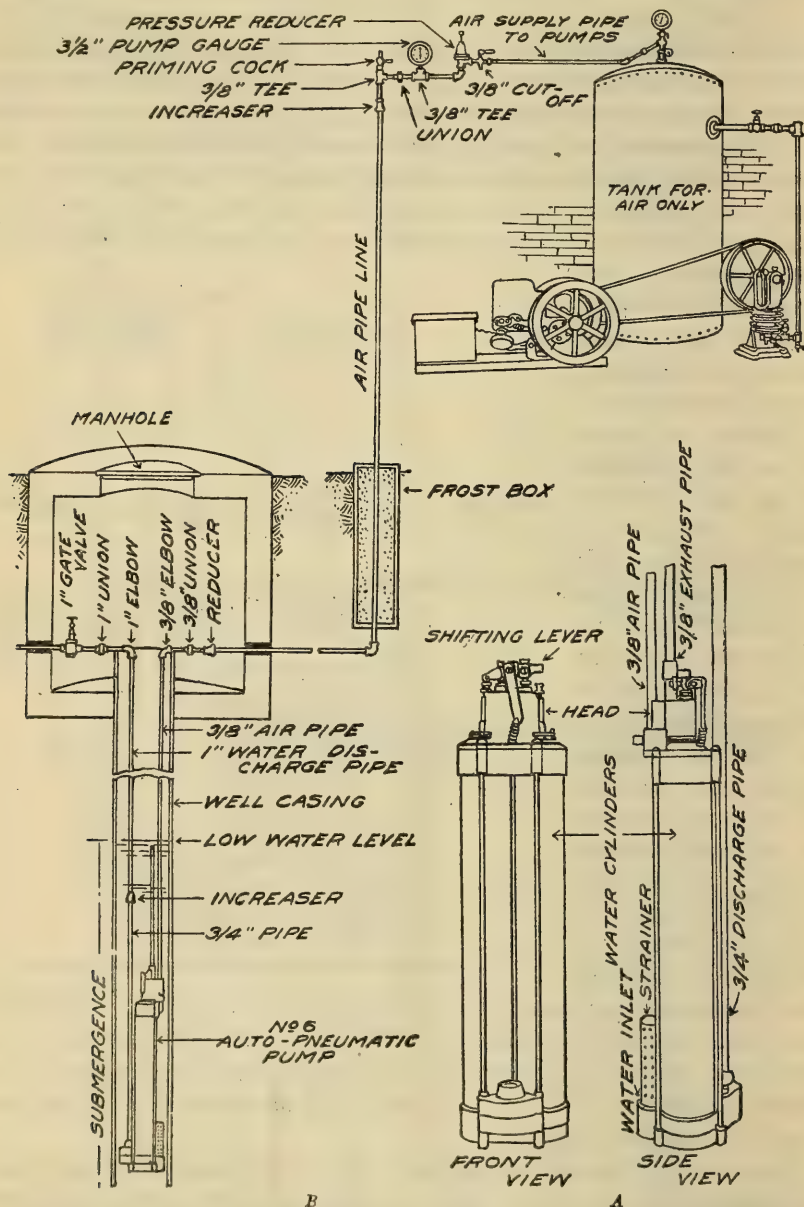


Fig. 17.—Working parts of an autopneumatic pumping system: A, Front and side view; B, entire working system as used in bored or cased wells.

required height in the building is recorded on the pump gauge placed on the air-pipe line between the reducer and the pump. The following table shows the number of gallons of water that can be

drawn from faucets with the pump under working pressures varying from 25 to 65 pounds and total starting pressures in a 1,000-gallon air tank varying from 40 to 100 pounds:

Pumping capacity of a 1,000-gallon air tank, in gallons, under varying internal pressures.

Work pressure on pump gauge.	Total pressure in air tank at start.						
	40 pounds.	50 pounds.	60 pounds.	70 pounds.	80 pounds.	90 pounds.	100 pounds.
Pounds.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
25	375	259	833	1,075	1,310	1,548	1,786
30	221	442	663	884	1,105	1,326	1,548
35	102	306	510	714	924	1,123	1,327
40		187	374	561	748	936	1,123
45		85	255	425	596	765	936
50			153	306	460	612	765
55			68	204	330	476	612
60				119	237	375	476
65				51	153	255	357

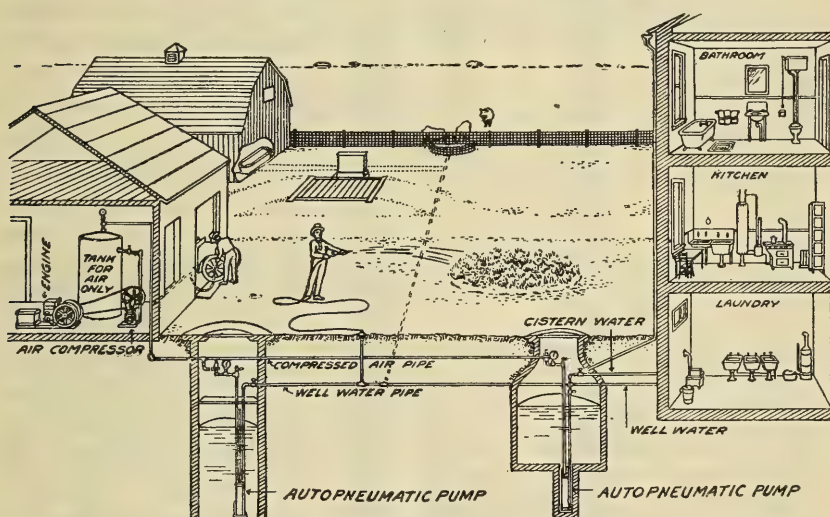


FIG. 18.—Application of autopneumatic system to a farm home.

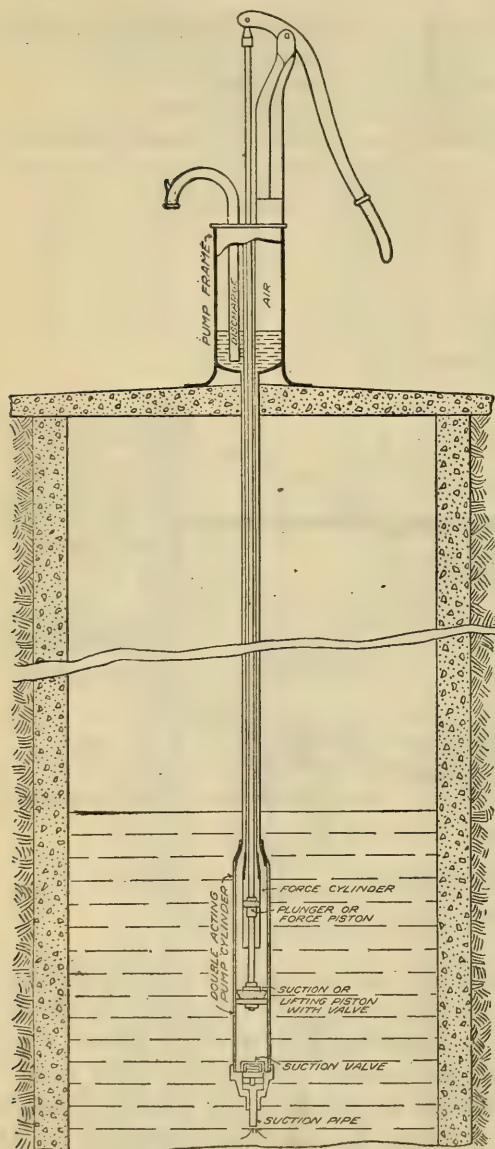
For air tanks of other than 1,000-gallon capacity divide the figures in the table by 1,000, move the decimal point three places to the left, and multiply the result by the capacity of the tank in gallons.

Assume, for example, that the height to which the water is to be raised and the pressure required to operate the pump, including friction, make necessary a working pressure of 40 pounds on the pump. Then if the initial pressure in the air tank is 50 pounds, 187 gallons of water can be delivered at the faucets before the pressure in the air tank becomes too low to operate the pump.

The autopneumatic pump can be used in wells, springs, or lakes where the water is free from sand and mud and does not have to be

lifted more than 100 feet, or where the working pressure on the pump does not exceed 65 pounds.

Figure 18 illustrates the application of this system to a farm home.



PUMPING.

The water level in shallow wells is usually near enough to the surface to be within the limits of suction. The limiting practical suction lift for a pump is about 20 feet, although it will vary with the elevation above sea level. This means that the pump cylinder which raises the water by suction in lift pumps and which raises by suction and also forces the water in force pumps should not be more than 20 feet above the water level in the well. To practically eliminate suction lift the cylinder may be submerged as shown in figure 19, thus making the cylinder and pump frame separate and connected only by a section of pipe. This prevents the valves from drying out and makes the pump self-priming. Force pumps often have two cylinders, and in deep wells it is necessary that the lower or suction cylinder be either submerged or within at least 15 feet of the water level. In

FIG. 19.—Force pump with cylinder submerged in shallow well.

the figure shown the forcing cylinder is within the suction cylinder. The suction of any type of pump must be air-tight.

To find the approximate discharge at each stroke of a pump in gallons use the following table:

Table of capacity of pumps.

Diameter of cylinder in inches.	Length of stroke in inches.									
	5	6	7	8	9	10	12	14	15	16
	Capacity per stroke in gallons.									
1	0.017	0.020	0.024	0.027	0.031	0.034	0.041	0.048	0.051	0.054
1 $\frac{1}{8}$	.022	.026	.030	.034	.039	.043	.052	.060	.065	.069
1 $\frac{1}{4}$	.027	.032	.037	.043	.048	.053	.064	.074	.079	.085
1 $\frac{3}{8}$	.032	.039	.044	.051	.058	.064	.077	.089	.096	.103
1 $\frac{1}{2}$	.038	.046	.054	.061	.069	.077	.092	.107	.115	.122
1 $\frac{5}{8}$	.052	.063	.073	.083	.094	.104	.125	.146	.156	.170
2	.068	.082	.095	.109	.122	.136	.163	.190	.204	.218
2 $\frac{1}{8}$	.086	.103	.121	.138	.155	.172	.206	.241	.258	.275
2 $\frac{1}{4}$	.106	.128	.149	.170	.191	.213	.255	.298	.319	.340
2 $\frac{3}{8}$	.129	.154	.180	.206	.231	.257	.309	.360	.386	.411
3	.153	.184	.214	.245	.275	.306	.367	.428	.459	.489
3 $\frac{1}{8}$	.179	.215	.251	.287	.323	.359	.431	.503	.539	.575
3 $\frac{1}{4}$	.208	.249	.292	.333	.375	.417	.499	.583	.625	.666
3 $\frac{3}{8}$	.239	.287	.335	.382	.430	.478	.574	.669	.717	.765
4	.272	.326	.381	.435	.490	.544	.653	.762	.816	.870
4 $\frac{1}{8}$	.307	.368	.429	.491	.553	.614	.737	.860	.921	.982
4 $\frac{1}{4}$	.344	.413	.482	.551	.619	.689	.826	.964	1.033	1.102
4 $\frac{3}{8}$	.384	.460	.537	.614	.690	.767	.920	1.073	1.150	1.227
5	.425	.510	.595	.680	.765	.850	1.020	1.190	1.275	1.360
5 $\frac{1}{8}$	.469	.562	.656	.750	.843	.937	1.124	1.311	1.405	1.499
5 $\frac{1}{4}$	.514	.617	.720	.823	.926	1.029	1.234	1.440	1.543	1.646
5 $\frac{3}{8}$	.562	.674	.787	.899	1.011	1.124	1.348	1.573	1.686	1.798
6	.612	.734	.857	.979	1.102	1.224	1.469	1.714	1.836	1.958

The discharge per stroke as shown by the above table may be multiplied by the number of strokes per minute to find the discharge in gallons per minute.

The power required for pumping will depend on the number of gallons per minute one wishes to pump and the total lift.

The total lift is the vertical distance from the surface of the water in the well to the highest faucet or to the storage tank plus the friction loss in the pipes. If the length of distribution pipe is over 100 feet the loss by frictional resistance in feet of lift should be determined and included in the total lift. The following table gives the frictional loss in feet of lift per 100 feet in pipes from $\frac{3}{4}$ to 4 inches in diameter, discharging from 5 to 40 gallons per minute.

Fractional loss in feet for 100 feet clean iron pipes.¹

Gallons per minute.	$\frac{3}{4}$ inch.	1 inch.	1 $\frac{1}{8}$ inches.	1 $\frac{1}{4}$ inches.	2 inches.	2 $\frac{1}{2}$ inches.	3 inches.	3 $\frac{1}{2}$ inches.	4 inches.
5	7.6	1.9	0.71	0.27	0.09	0.05	0.01	-----	-----
10	29.9	7.3	1.4	1.0	.28	.09	.05	0.01	-----
15	66.0	16.1	5.5	2.2	.57	.18	.09	.05	0.02
20	115.0	28.0	9.5	4.8	.96	.32	.13	.07	.03
25	179.0	43.7	14.7	6.0	1.7	.48	.23	.09	.05
30	264.0	63.2	21.0	8.6	2.1	.69	.30	.14	.07
35	372.0	85.1	28.9	11.6	2.7	.92	.39	.20	.11
40	461.0	110.0	37.0	14.9	3.7	1.2	.53	.25	.14

¹ Ellis and Howland's experiments.

Water weighs 62.5 pounds per cubic foot and there are 7.48 gallons in a cubic foot. Divide the number of gallons pumped per minute by 7.48 to get the cubic feet pumped per minute. Multiply the cubic feet by 62.5 pounds to get the weight of water pumped per minute. Multiply the weight by the total lift, which will give the foot-pounds of work per minute; 33,000 foot-pounds per minute equal 1 horsepower. Divide the foot-pounds per minute by 33,000 and the result will be horsepower. The horsepower as computed

from the quantity pumped per minute and the total lift should be doubled, as a pumping outfit usually has an efficiency of about 50 per cent. In general, from 1 to 3 horsepower is all that is required for ordinary farm pumping. In cases where water for the house only is wanted, $\frac{1}{2}$ to $\frac{3}{4}$ of a horsepower is sufficient.

TYPES OF PUMPS.

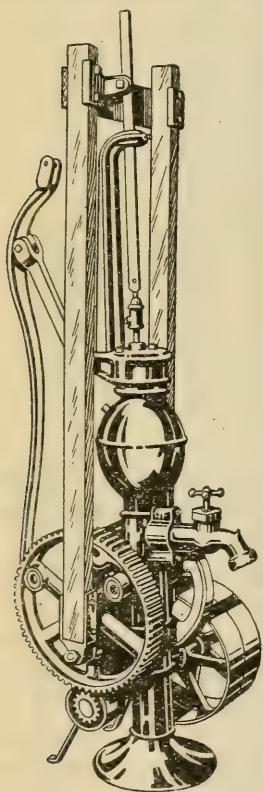
There are several types of pumps which may be used in farm pumping. The most common are the ordinary lift pumps which simply raise the water to the ground surface from a shallow well. For elevated tank systems and pneumatic tank systems the combination lift and force pump is necessary. If a special air pump or compressor is not employed it is necessary that a combination air and water pump be used for pneumatic tanks, especially in pumping from deep wells.

There are many types of hand force pumps for shallow and deep well pumping which may be applied to either elevated tank or pneumatic tank systems.

FIG. 20.—Pumping jack for either deep or shallow well pumping.

Figure 15, page 18, shows a deep-well windmill pumping outfit applied to a pneumatic tank system, and figure 13, page 16, shows a shallow well windmill pumping outfit supplying water to a tank on the windmill tower. Figure 20 is a pumping jack which may be connected with a deep or shallow well pumping outfit applied to either system. This jack may be operated by gas engine or electric motor. Figure 21 shows two other types of windmill force pumps, *A* for shallow wells, and *B* for deep wells.

In obtaining information from the manufacturers of pumping equipment as to the particular equipment which will suit certain needs, the power required, etc., it is well to send data on the following: The source of water supply, whether a well, spring, or surface



supply; inside diameter and total depth of the well; the distance from the ground surface to the water level in the well; the flow of the well; the number of gallons to be pumped per hour; the relative positions of the water supply and the point to which the water is to be forced; the position in which the pump is to be placed; one's preference as to pneumatic tank, elevated tank, or autopneumatic system; the kind of power to be used, and whether or not power is already available, such as electric motors, windmills, or gasoline engines, with a complete description of the power, its revolutions per minute, voltage, cycles, phase, direct or alternating current, etc.

Where a supply of pure water may be obtained in the immediate neighborhood, which is so situated that a considerable fall may be obtained within a reasonable distance, a hydraulic ram may be used for pumping.

THE HYDRAULIC RAM—
HINTS ON INSTALLATION
AND OPERATION.

The hydraulic ram is a simple though wasteful machine, which utilizes the momentum of a stream of water falling a small height to elevate a

portion of that water to a greater height. A complete installation consists of a drive pipe, ram, and delivery pipe, and the ram itself consists of an air chamber, dash valve, delivery valve, and body pipe.

The hydraulic ram is usually used to elevate water from a pure spring. Water may be elevated from streams to stock tanks, but this water should not be used for household purposes. The flow of the spring should not be less than one-half gallon per minute. It is necessary that there be considerable difference in elevation between

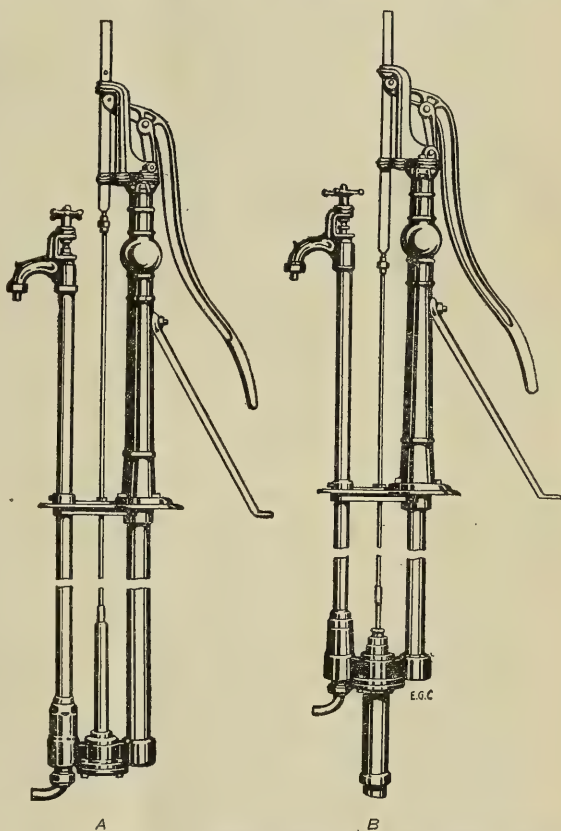


FIG. 21.—Two types of windmill force pump: *A*, For shallow wells; *B*, for deep wells.

the level of the supply and a convenient location for the ram within a reasonable distance. Figure 22 shows a cross section of a simple type of hydraulic ram. Figure 23 shows the usual relative positions of spring, ram, and storage tank.

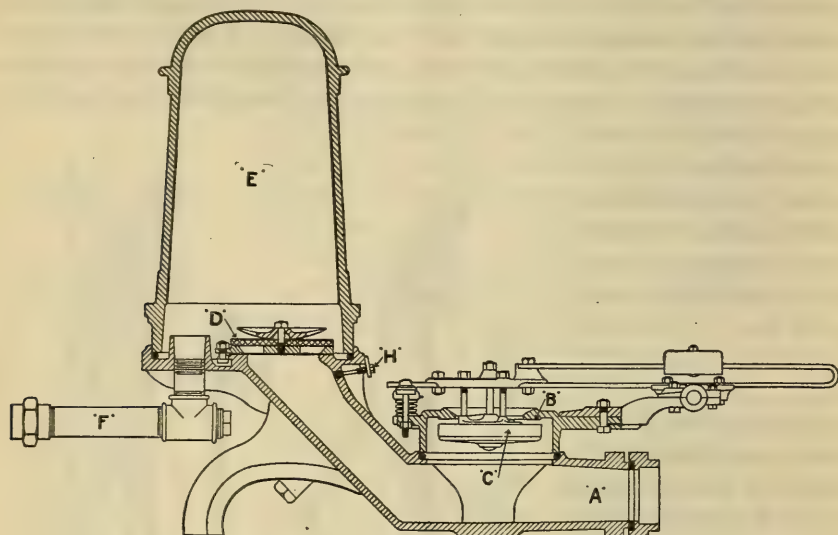


FIG. 22.—Cross section of simple type of hydraulic ram.

The operation of a ram may be briefly explained as follows: The water flowing down the drive pipe acquires a certain energy due to its weight and velocity and upon entering the body pipe of the ram strikes

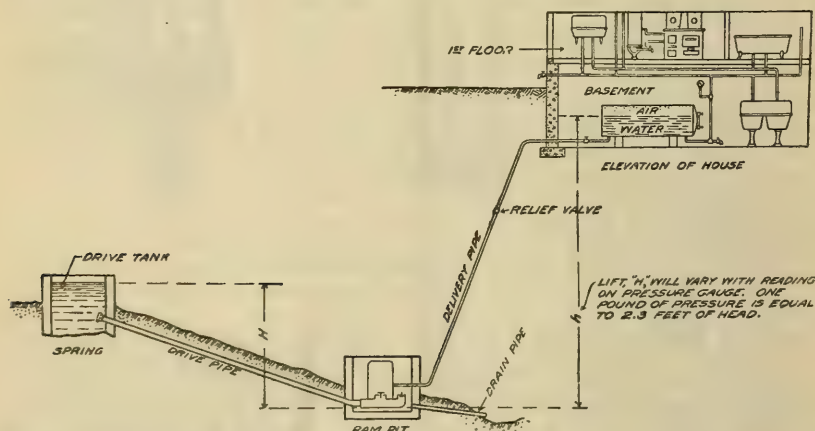


FIG. 23.—Hydraulic ram pumping to a pneumatic tank supply system, showing usual relative position of spring, ram, and storage tank.

the open dash valve with considerable force, which is sufficient to close it. The result is that the water piles up and exerts an interior pressure, which causes the delivery valve to open, admitting water

into the air chamber. (See fig. 22.) The water then rebounds back up the drive pipe until forced down again by the weight of the water in the drive pipe, and the operation is repeated. During each momentary reflow a small quantity of water is forced into the air chamber, compressing the air. The resulting air pressure forces water up the delivery pipe to the point of delivery. The operation of a ram is continuous, once started, until the valves become worn. The ordinary small ram completes its cycle about 60 times a minute, the length of stroke of the dash valve governing the number of pulsations per minute.

The length of drive pipe is most important and is governed by the ratio of the fall to the elevation. If too long or too short the automatic supply of air is interfered with and the efficiency impaired. The length of drive pipe is usually about 7 times the height of fall, although this may vary between 5 and 10, depending on the height and distance to which water is to be delivered. The diameter of the drive pipe is usually twice that of the discharge pipe.

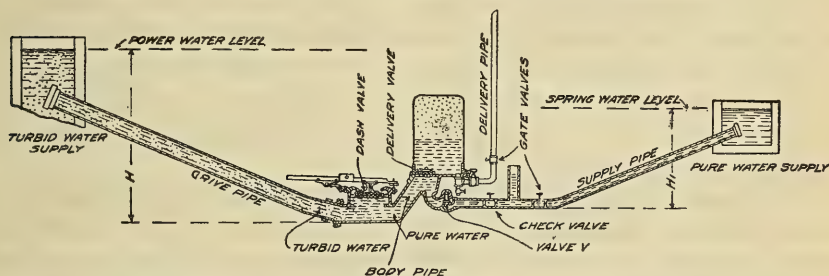


FIG. 24.—Double acting hydraulic ram, showing method of using a turbid creek supply to pump clear spring water.

The proper size of ram to suit certain conditions depends on the following: (1) The flow of water from the source of supply, determined by the time necessary to fill a vessel of known capacity or by weir measurement; (2) the difference between the level of the supply and the lowest point within a reasonable distance for the location of the ram; (3) the distance between the source of supply and the proposed location of the ram; (4) the difference in level between the ram location and the highest point to which water is to be delivered; (5) length of pipe necessary to conduct the water to the point of delivery. In purchasing a ram this information should be sent to manufacturers.

Sometimes a double-acting ram is installed where there is a spring too small to operate a single-acting ram but located near a brook from which an ample supply and fall can be obtained to operate the ram. These are so constructed that if properly installed under a fall of at least 2 feet below the spring and 3 feet below the brook it is impossible to deliver anything but the spring water. Figure 24 illustrates

this method. If this method is preferred, it should be so stated in purchasing. The following table gives approximate sizes of hydraulic rams to suit certain conditions.

Sizes of hydraulic rams.

Number.	Dimensions.			Size of drive pipe.	Size of delivery pipe.	Quantity per minute required to operate engine.	Least fall recommended.
	Height.	Length.	Width.				
	<i>Ft. ins.</i>	<i>Ft. ins.</i>	<i>Ft. ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Gallons.</i>	<i>Feet.</i>
10.....	2 2	2 10	0 12	1½	¾	2-6	2
15.....	2 2	3 0	0 12	1½	¾	6-12	2
20.....	2 5	3 3	1 2	2	1	8-18	2
25.....	2 5	3 4	1 3	2½	1	12-28	2
30.....	2 7	3 7	1 3	3	1½	20-40	2
40.....	3 7	4 9	1 8	4	2	30-75	2

There are four separate problems connected with the hydraulic ram. These, with practical examples, are described by W. C. Davidson¹ as follows: (1) Given the fall, lift, and quantity of water desired, find the necessary supply at spring. (2) Given the lift, quantity of drive water, and quantity of water desired, find the fall required. (3) Given the fall, lift, and quantity of drive water, find the quantity of water supplied to the storage tank. (4) Given the fall, quantity of drive water, and quantity of water desired, find how high this water can be pumped.

The computations which follow are based upon an approximate rule, which is stated as follows: Multiply the fall in feet by the quantity of water supplied to the ram in gallons per minute, divide the product by the height the water is to be raised, and the result will be in gallons per minute. This may be expressed in an equation as follows:

$q = \frac{Q \times H}{h}$, in which Q =supply of spring in gallons per minute.

H =fall in feet from spring to ram. h =height of storage tank above the ram in feet. q =quantity of water pumped in gallons per minute. The result should be reduced by about one-third to allow for friction.

Example 1. It is desired to find the quantity of drive water in the spring necessary to raise 8 gallons per minute to a height of 60 feet, when the head of drive water on the ram is 8 feet. Substituting in the equation $Q = \frac{h \times q}{H} = \frac{8 \times 60}{8} = 60$ gallons per minute.

In this case about one-third of the result should be added to allow for friction in pipes, valves, etc., making the necessary drive water supply 80 gallons.

¹ Missouri Bd. Agr. Mo. Bul., 10 (1912), No. 2.

Example 2. It is desired to find the necessary fall from the spring to the ram in order to supply the storage tank with 2 gallons per minute, when the drive water supply in the spring is 10 gallons per minute and the height to which the water is to be pumped is 40 feet.

Substituting in the equation $H = \frac{h \times q}{Q} = \frac{2 \times 40}{10} = 8$ feet. Add one-third to allow for friction, making the total fall necessary 10.66 feet.

Example 3. It is desired to find how much water will be delivered into the storage tank if the drive water supply is 6 gallons per minute, the fall is 10 feet, and the height to which the water is to be pumped is 40 feet. Substituting in the equation $q = \frac{Q \times H}{h} = \frac{6 \times 10}{40} = 1.5$ gallons per minute. Deduct one-third of this result to allow for friction, making the quantity delivered per minute 1 gallon.

Example 4. It is desired to find how high 1 gallon per minute can be pumped if the drive water supply is 4 gallons per minute and the fall is 15 feet. Substituting in the equation $h = \frac{Q \times H}{q} = \frac{4 \times 15}{1} = 60$ feet. Deduct one-third to allow for friction, making the result 40 feet.

The above computations are only approximate, but should give a good general idea of the operation of a ram.

The following table gives commercial estimates of the quantities of water delivered in 24 hours under certain conditions:

Capacity of hydraulic rams.

Power head in feet.	Pumping head in feet—																	
	4	10	15	20	30	40	50	60	70	80	90	100	120	140	160	180	200	
2	540	192	128	96	64	43	29	24	20	17	15	13	11	10	9	8	7	
3	301	192	144	96	72	58	43	37	32	27	24	21	18	16	14	12	11	
4	432	256	192	128	96	77	64	55	43	38	34	29	24	21	18	16	14	
5	540	345	240	160	120	96	80	69	60	53	43	30	26	23	20	18	16	
6	432	302	192	144	115	96	82	72	64	57	43	31	27	24	21	18	16	
7	505	378	235	168	134	112	96	84	75	67	50	36	31	28	25	22	20	
8	432	270	192	154	128	110	96	86	77	64	55	43	38	34	30	27	24	
9	485	300	216	173	144	124	108	96	86	72	62	54	43	39	35	31	28	
10	432	252	192	160	137	120	107	96	80	68	60	53	43	38	34	30	27	
12	430	301	230	192	165	144	128	115	96	82	72	64	57	51	45	40	36	
14	505	353	270	224	192	168	150	135	112	96	84	75	67	60	53	47	42	
16	432	323	257	220	192	171	154	128	110	96	85	77	64	55	43	38	34	
18	486	390	303	247	216	192	173	144	124	108	96	86	72	62	54	43	39	
20	540	430	336	288	240	214	192	160	137	120	107	96	80	68	60	53	43	
22	475	370	303	264	235	212	176	151	132	118	105	92	80	70	62	54	43	
24	520	405	346	288	256	230	192	164	144	128	115	100	88	78	68	60	53	
26	470	375	328	278	250	208	178	156	139	125	112	96	84	75	67	60	53	
28	505	430	354	300	269	224	192	168	149	134	120	107	96	86	77	64	55	
30	540	465	405	336	288	240	206	180	160	144	128	115	100	88	78	68	60	

¹ Multiply factor opposite "power head" and under "pumping head" by the number of gallons per minute used by the engine and the result will be the number of gallons delivered per day. Example: With a supply of 6 gallons per minute, 10 feet fall, 40 feet elevation, No. 10 or 15 engine will deliver 1,512 gallons per day; $6 \times 252 = 1,512$.

This table will give only approximate quantities since the results will vary with the length of delivery pipe. Due consideration of pipe friction will give more correct results.

The efficiency developed is governed by the ratio of fall to pumping head, being greatest for a ratio of 1 to 25 or 1 to 3, and the ram will not usually work well when the ratio is over 1 to 25, friction in the delivery pipe being duly considered.

The spring should be walled in to form a reservoir as shown in the discussion of springs, page 12. If a stream is used it should be dammed back until a sufficient flow and fall is obtained.

Rams may be obtained to supply water for both elevated tank and pneumatic tank systems. In purchasing a ram this should also be specified.

In order to obtain the desired fall it is often necessary to convey the water a greater distance than the length of drive pipe used. Figure 25 illustrates two methods of securing the necessary fall.

It is necessary to provide a shelter for the hydraulic ram to prevent freezing in cold weather. The pipes should also be placed below the frost line. In setting a ram the foundation should be firm and level. The drive pipe should be laid on a perfectly straight incline without

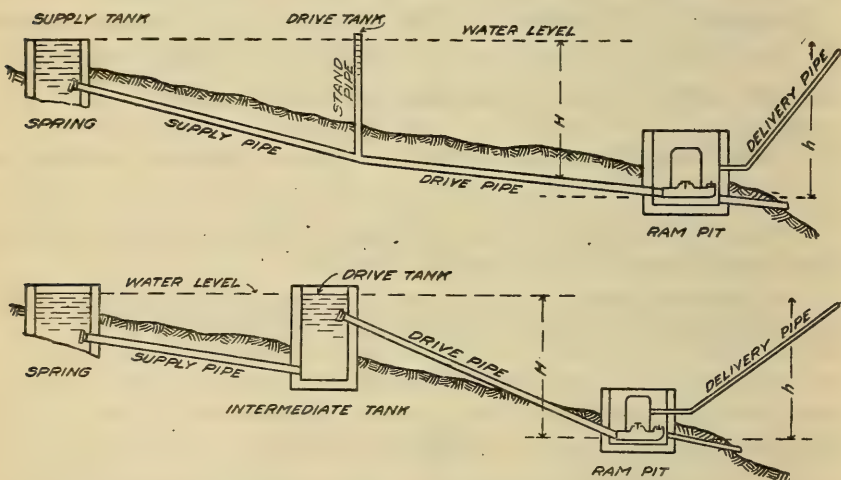


FIG. 25.—Two methods of securing the necessary fall in drive pipe.

bends or curves, except where the pipe enters the ram, and this should be made by bending the pipe. Fittings should not be used. The upper end of the drive pipe should be sufficiently below the surface of the water to prevent air suction—at least a foot. A good open strainer should be provided at the upper end also. Above all things the drive pipe should be air-tight.

The delivery pipe may be laid with the necessary bends, according to the usual practice in laying water pipes, but all pipes should be connected before starting the engine and they should be left uncovered until all leaks are stopped. However, there should be as few bends and elbows in the delivery pipe as possible in order to reduce friction.

Manufacturers of hydraulic rams should supply directions for the proper installation, operation, and care of their particular rams, and these directions should be carefully followed.

PLUMBING.

IMPORTANT POINTS TO BE CONSIDERED.

The important points to be considered in the arrangement of a plumbing system are (1) durability of material and construction, and (2) simplicity. Avoid any complication of pipes and arrange the water pipes so as to carry the water to the point of discharge in as nearly a straight line as possible. The use of lead pipe or lead-lined receptacles for drinking water should be avoided in small private systems.

WATER PLUMBING.

The main pipe from the supply tank should be about $1\frac{1}{4}$ inches in diameter and never less than 1 inch. It leads to the kitchen range and then branches. One branch conveys cold water to the fixtures and the other conveys water through the heater, through the hot-water tank, and thence to the hot-water fixtures. The hot-water pipe should parallel the cold-water pipe but should not be so close to it that the temperature of either will affect that of the other. The arrangement of water pipes, hot-water tank, etc., is shown in figure 14. The hot-water pipes are shown in black. All water pipes should be put in with red lead and all fittings should be screwed tight. The natural direction of travel of hot water is upward, and this should be aided, in arranging the hot-water pipes, as much as possible.

The sizes of pipes generally used for supplying water to the various fixtures are given in the following table:

Size of water pipes in building.

Supply branches.	Low pressure.	High pressure.	Supply branches.	Low pressure.	High pressure.
	<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>
To bath cocks.....	$\frac{3}{4}$ -1	$\frac{3}{4}$ - $\frac{1}{2}$	To water-closet flush pipes....	$1\frac{1}{4}$ - $1\frac{1}{2}$	.....
To basin cocks.....	$\frac{1}{2}$ - $\frac{3}{4}$	$\frac{1}{2}$ - $\frac{3}{4}$	To kitchen sinks.....	$\frac{3}{4}$ -1	$\frac{1}{2}$ - $\frac{3}{4}$
To water-closet flush tank....	$\frac{1}{2}$ - $\frac{3}{4}$	$\frac{1}{2}$ - $\frac{3}{4}$	To pantry sinks.....	$\frac{3}{4}$ -1	$\frac{1}{2}$ - $\frac{3}{4}$
To water-closet flush valve....	1- $1\frac{1}{4}$	$\frac{3}{4}$ -1	To slop sinks.....	$\frac{3}{4}$ -1	$\frac{1}{2}$ - $\frac{3}{4}$

All water pipes should have sufficient slant to drain them back into the tank or drainage system, and a drain pipe and cock should be provided at the low point in the system, so that in extremely cold weather the system may be drained into the sewer or drainage system to prevent freezing. This necessitates a stop cock on the pressure-tank outlet to prevent draining the tank.

Pipes should be kept from the outer walls to prevent freezing, and pipes located where they are in any danger whatever of freezing should be boxed in sawdust or some other nonconducting material.

Since a plentiful supply of hot water is convenient and a large quantity retains heat for some time, it is well to provide a fairly large hot-water tank. However, the size of boiler depends on the existing

conditions, such as the water supply and the size of building. A safe rule is to allow a 35 or 40 gallon boiler to a building having one bathroom and to add 30 gallons additional capacity for every extra bathroom. One hundred square inches of water-back heating surface is sufficient for a 40-gallon boiler.

Boilers should be galvanized inside and out, particularly inside. Copper boilers are preferable if properly coated inside with block tin.

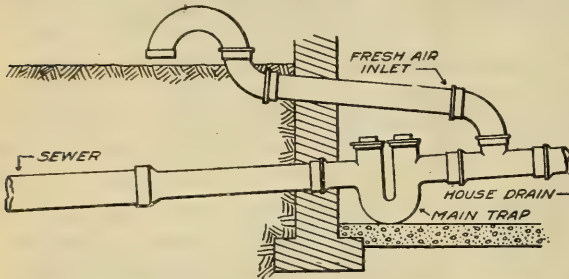


FIG. 26.—Sewer trap at house foundation, showing ventilator.

These are classed as light, heavy, and extra heavy, the latter being tested to 150 pounds water pressure. Ordinary steel or iron boilers are tested to 150 pounds water pressure and extra heavy ones to 250 pounds pressure.

The latter should be used when the gauge pressure is more than 40 pounds per square inch. The following table gives standard sizes of galvanized boilers:

Standard sizes of galvanized boilers.

Capacity.	Length.	Diameter.	Capacity.	Length.	Diameter.
<i>Gallons.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Gallons.</i>	<i>Feet.</i>	<i>Inches.</i>
18	3	12	48	6	14
21	3½	12	52	5	16
24	4	12	53	4	18
24	3	14	63	6	16
27	4½	12	66	5	18
28	3½	14	79	6	18
30	5	12	82	5	20
32	4	14	98	6	20
35	5	13	100	5	22
36	6	12	120	6	22
36	4½	14	120	5	24
40	5	14	144	6	24
42	4	16	168	7	24
47	4½	16	182	8	24

SEWER PLUMBING.

The sewer plumbing serves as a drain for the water plumbing. The drainage system should be so constructed as to carry away completely everything emptied into it, and it should be constantly vented, frequently and thoroughly flushed, and have each of its openings into the house securely guarded. All drains, soil pipe, and waste pipe should be water-tight and air-tight. The soil pipe or house-drainage main begins at the sewer opening and passes up through the house as nearly vertical as possible and out through the roof for free ventilation. It should be at least 4 inches in diameter, of extra heavy cast iron, and all joints should be tightly calked with lead and oakum. All discharge from the wash basins, sinks, and toilets empties into

the soil pipe, and connections should be tightly made. The sewer inside the cellar wall should always be soil pipe; tile should never be used except outside of the wall. A soil-pipe trap should be provided at the house foundation, as shown in figure 26. Every fixture should have a trap to prevent foul air from coming back through the waste pipe. Vent pipes should be provided on all waste pipes to prevent siphonage and the consequent destroying of the traps. Figure 27 (p. 34) shows a good arrangement of sewer plumbing.¹ Note the traps and vent pipes on each waste pipe. The least sizes of waste and vent pipes are given in the table below.

Sizes of waste and vent pipes.

Name of pipe.	Diameter.	Name of pipe.	Diameter.
	<i>Inches.</i>		<i>Inches.</i>
Main and branch soil pipe	4	Wash tubs, 1½-inch waste pipe to 2-inch trap for 2 tubs	1½-2
Main waste pipe	2	Waste pipe for 3 or 4 tubs	2
Branch waste pipes for kitchen sinks ..	2	Main vents and long branches	2
Bath or sink waste pipe	1½-2	Branch vents for traps over 2 inches ..	2
Basin waste pipe	1½-1½	Branch vents for traps less than 2 inches	1½
Pantry sink waste pipe	1½		
Water-closet trap	3½-4		

All plumbing should be tested by filling with water or smoke to detect leaks.

SEWAGE PURIFICATION AND DISPOSAL.

The problem of the purification and disposal of farm sewage by small private systems differs somewhat from that of city sewage disposal, owing principally to the extreme fluctuations in flow, small size of the system, fresh character, and variation in the quality of the sewage.

The process of sewage disposal is partly mechanical and partly bacterial, consisting of (1) preliminary or tank treatment and of (2) final treatment, which is application to a natural soil by surface or subsurface distribution or to a specially prepared filter.

PRELIMINARY OR SEPTIC-TANK TREATMENT.

The exact nature of the action which takes place in a septic tank is a subject of dispute among sanitary experts and bacteriologists. Several theories have been advanced, but it is apparent that no definite conclusion has been reached. Some authorities advocate the use of open ventilated tanks, others advocate the use of air-tight tanks.

Experience has shown that, in a small sewage disposal system, a dark, air-tight tank of sufficient capacity and so constructed that sewage may remain in it entirely at rest for a period of from 18 to 24

¹ Univ. Mo. Engin. Expt. Sta. Bul. 3.

hours gives the best results and the least annoyance. The solid matter settles out in such a tank and, according to the theory at present accepted, it is partially liquefied, deodorized, and destroyed

by countless numbers of bacteria, which thrive in filth and live without air. Some authorities assert that these bacteria also slightly affect the dissolved organic matter in raw liquid sewage.

In such a tank a thick scum forms on the surface of the sewage, which protects the bacteria from the incoming air and is evidence of good bacterial action. The breaking up or disturbance of this scum will destroy the bacterial action for the time being and is likely to cause considerable annoyance by bad odors.

FINAL TREATMENT.

It is found that the septic tank effects only about 40 per cent purification. The liquefying action in the tank, however, makes it possible to subject the sewage to a final treatment by filtration or distribution in a natural soil.

This final purification

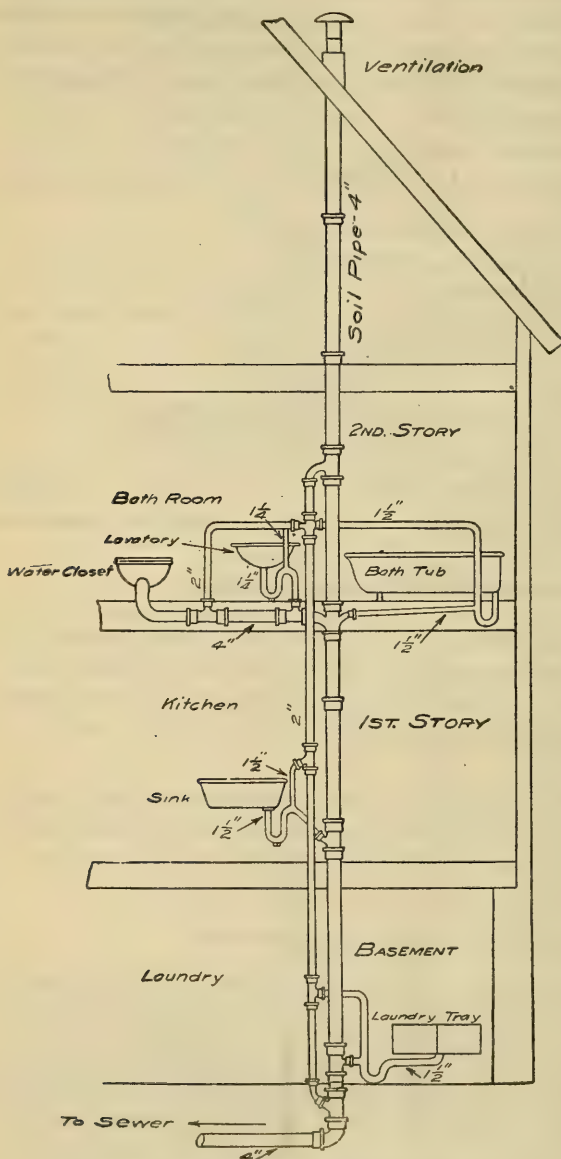


FIG. 27.—Plumbing system for sewage disposal.

is effected by means of bacteria which work in the air. Therefore it is necessary that the sewage be applied to the final disposal system in intermittent doses so that the system may have a chance to air out.

If the sewage is applied continuously and in such quantities that the system is kept saturated, the filter or disposal area becomes waterlogged and "sewage sick" and ceases to be effective. It is therefore necessary that the final treatment system be of sufficient capacity to dispose of each dose of sewage quickly.

DOUBLE-CHAMBER SEPTIC-TANK SYSTEMS.

The septic tank for a small sewage-disposal system should ordinarily consist of two chambers. In this type of tank the sewage is received, settled, and partially purified in one chamber and collected and discharged from a second chamber. This type of tank if properly designed should give satisfactory operation, since the sewage in the settling chamber suffers little disturbance, and the discharge to the final disposal system may be made intermittent by means of an automatic siphon placed in the discharge chamber.

DESIGN.

Practice indicates that the settling chamber of a small septic tank should have a capacity of from 5 to 15 cubic feet or from 40 to 80 gallons per person in the family. Some allow an average of 10 or 11 cubic feet per person. The best results are obtained when the capacity approaches the larger limit, so that 18 to 36 hours' sewage from the house may be held at one time, thus causing the sewage to remain in the tank and undergo sedimentation and bacterial action for this length of time. But care should be taken not to make the tank so large that liquefied sewage will remain in it more than 36 hours, for in that event putrefaction is likely to set in. For this reason one should make an accurate estimate of the daily sewage flow, which will be practically equal to the daily water consumption. Although a depth of 3 feet may be sufficient for some classes of sewage, it is better to have the depth from 4 to 8 feet, according to the number of people, in order to give the sludge a good chance to settle and liquefy. The width of the chamber may ordinarily be about one-third or one-half the length, although this may vary for economy and convenience. The width should not be less than 3 feet, however.

The inlet from the house should be provided with an elbow, so that the discharge will be at least a foot below the contained sewage, thus preventing disturbance of the surface scum. The outlet from the settling chamber should be equipped in the same way. Where the entrance and discharge velocities are very strong, baffle walls of wood or concrete should be placed before these openings to break the current. These precautions are especially beneficial in the smaller-sized tanks.

The discharge chamber should be of such capacity and depth as to discharge about every 10 to 12 hours. It may be desirable to discharge at more or less frequent intervals, according to the nature of the soil in the disposal area, and this may be controlled by the arrangement of discharge chamber and siphon. Where little outlet fall is available it is possible to so construct the discharge chamber that its floor will be considerably above that of the settling chamber.

The capacity and depth of discharge chamber and the size of siphon will depend on the number of persons served and the means of disposal. If a sand filter is used or a distribution system in heavy loam, the discharge chamber must be larger and deeper, in order that the discharge interval may be lengthened and the distribution system be given ample time to aerate. If the distribution is in sandy or very porous soil the discharge may be more frequent.

The following table of dimensions of septic tanks suggests sizes of settling and discharge chambers and the corresponding siphon sizes to apply to various average conditions. The depths of siphon chamber given are the minimum allowable.

Dimensions of septic tanks.

Number persons.	Settling chamber.			Siphon chamber.						Siphon diam-ter.
				Sand filter or heavy loam distribution.			Sandy or porous soil distribution.			
	Width inside.	Length inside.	Depth.	Width inside.	Length inside.	Minimum depth.	Width inside.	Length inside.	Minimum depth.	
	Feet.	Feet.	Feet.	Feet.	Feet.	Ft. in.	Feet.	Feet.	Ft. in.		Inches.
6	4	6	3½	4	3	2 4	3	2	2 4	3
8	4	6½	4	4	4	2 4	3	2½	2 4	3
12	4	7	5	4	5	2 5	3	4	2 5	4
15	4	8	5	4	6	2 5	3	4	2 5	4
25	4	10	5	4	6½	3 2	3½	4	3 2	5
35	4½	12	5	4	6½	3 2	3½	4½	3 2	5

The above table is computed on the basis that the inlet and outlet of the settling chamber should be placed with their inverts 12 inches below the roof of the tank, thus making the depth of sewage in both settling and discharge chamber 12 inches less than the mean inside depth.

The tank dimensions given in the above table, it should be remembered, are for average cases only, and are not standard for all such cases. They are subject to such variations to suit local conditions as the farmer's judgment indicates; yet care should be taken not to vary any of the essential dimensions and not to go below the given minimum depth of siphon chamber.

Figure 28 shows a type of double chamber septic tank for a family of six people, designed by W. C. Davidson.¹ Figure 29 is another

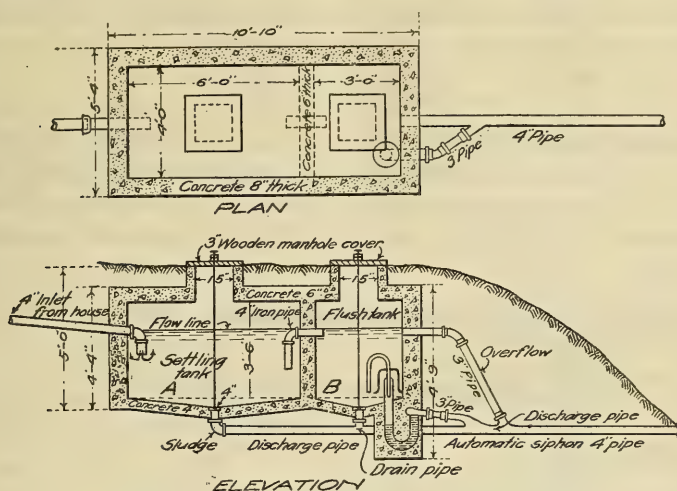
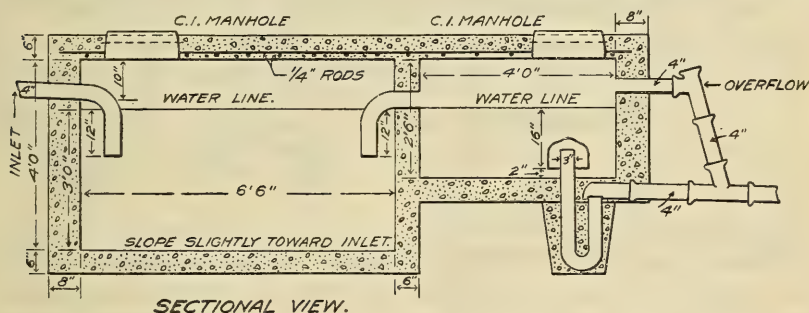
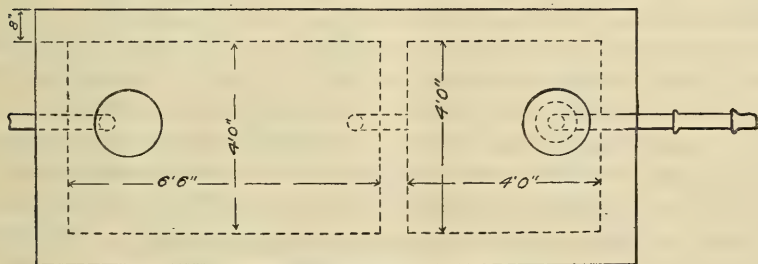


FIG. 28.—Double chamber septic tank for six people, suited to conditions where plenty of outlet fall is available.

type of septic tank for a family of eight people. These tanks are suited to conditions where plenty of outlet fall is available. Figure



SECTIONAL VIEW.



TOP VIEW.

FIG. 29.—Double chamber septic tank for eight people.

30 is a double-chamber tank for a family of six persons, designed by C. A. Ocock of the Wisconsin Agricultural Experiment Station.²

¹ Univ. Mo. Engin. Expt. Sta. Bul. 3.

² Wisconsin Sta. Circ. Inform. 34.

This tank is suited to flat ground where outlet fall is difficult to obtain, as will be noted by the difference in elevation between the floors of the two chambers. For satisfactory operation a small septic tank should not be built of smaller size than for six persons.

LOCATION AND CONSTRUCTION.

The septic tank, although air-tight and supposedly water-tight, should be located as far from the house and the well or spring as convenience and local surroundings will permit, thus reducing the danger of pollution or nuisance in case of leakage or improper operation of the system.

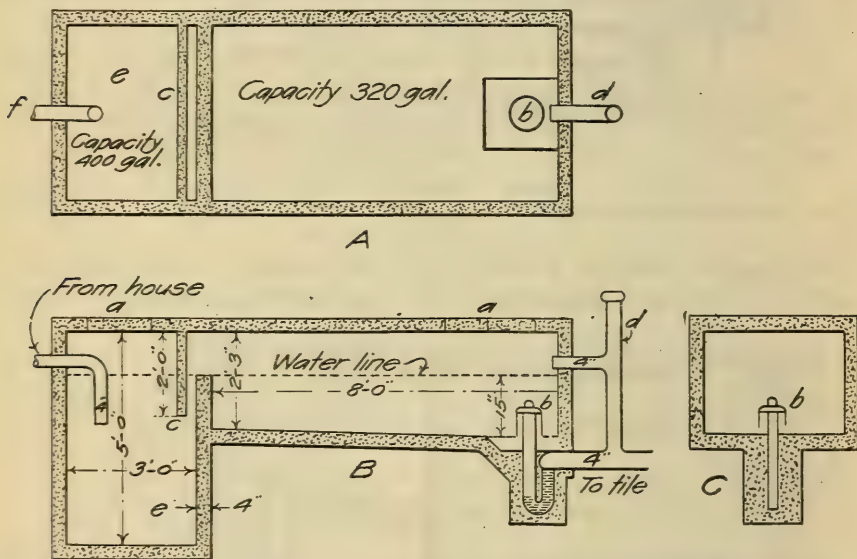


FIG. 30.—Double chamber septic tank for family of six people, suitable to conditions where outlet fall is difficult to obtain.

The sewer from the house should be of vitrified sewer pipe, usually of 4 inches size, with tightly cemented joints, and should be laid to a grade not less than 9 inches per 100 feet. Where the fall from the house to the tank is excessive, it is a good idea to lay the last 100 feet of tile to the minimum grade to break up entrance velocity.

It is assumed that the farmer has a working knowledge of small concrete structures.¹ The septic tank should be constructed as nearly water-tight as possible, preferably of concrete. The walls should be 6 or 8 inches thick, the floor 4 to 6 inches thick, and the roof about 6 inches thick and reenforced. Some means should be provided at the bottom to facilitate the cleaning out of settled sludge. Either the floor may be sloped toward the inlet end for this purpose or a pipe

¹ U. S. Dept. Agr., Farmers' Bul. 461.

with a valve may be installed below the tank, as shown respectively in figures 29 and 28. The discharge chamber should be fitted with an outlet set above the siphon which will allow the sewage to escape in case the siphon becomes clogged.

A concrete mixture of 1 part cement to 2 or $2\frac{1}{2}$ parts sand to 4 or 5 parts of broken stone or gravel should be used in the construction of the tank, and it is a good idea to use the oil-mixed method previously noted (p. 4) to help to waterproof the concrete.

THE AUTOMATIC SIPHON.

The automatic siphon may be installed to operate as frequently as may seem desirable. Figure 31 shows a 3 or 4 inch automatic siphon installed. The siphon operates as follows: As the liquid enters the discharge chamber its weight increases with increasing depth, and the air between the water surface in the bell and the water inside the "siphon leg" is compressed. As the water outside increases in

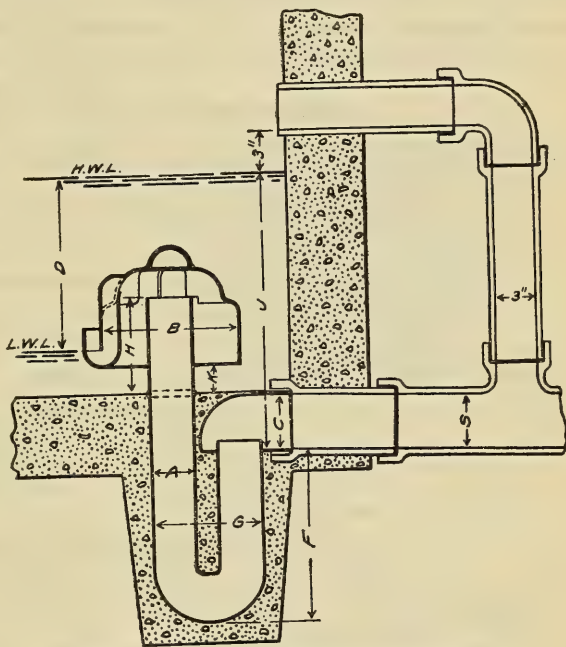


FIG. 31.—Three-inch or four-inch automatic siphon installed.

depth the compression inside becomes greater until the water outside reaches the drawing or discharge depth for the siphon. Then the inside pressure is sufficient to force the water in the siphon leg around the bend, instantly relieving the compression. The water from the tank then rushes in to fill up the space which was occupied by the air and starts the siphon, which continues until the outside and inside pressures are again equalized.

The following table gives working data and dimensions, as shown in figure 31, to be used in installing 3, 4, and 5 inch siphons. Sizes of 5 inches and over are constructed a little differently from the 3 and 4 inch sizes, although the working principles are the same.

Dimensions for automatic siphons.

Dimension.	Reference letter.	Inches.	Inches.	Inches.
Diameter of siphon.....	A	3	4	5
Diameter of bell.....	B	10	12	15
Diameter of discharge head.....	C	4	4	6
Drawing depth.....	D	13	14	23
Depth of trap.....	F	12	13	22
Width of trap.....	G	10	12	14
Height above floor.....	H	7 $\frac{1}{2}$	8 $\frac{1}{2}$	9 $\frac{1}{2}$
Clearance under bell.....	K	2	2	3
Diameter of carrier.....	S	4	4-6	6-8
Invert to discharge line.....	J	20 $\frac{1}{2}$	22 $\frac{1}{2}$	33 $\frac{1}{2}$
Average discharge per second.....cubic feet.....		0.16	0.35	0.73

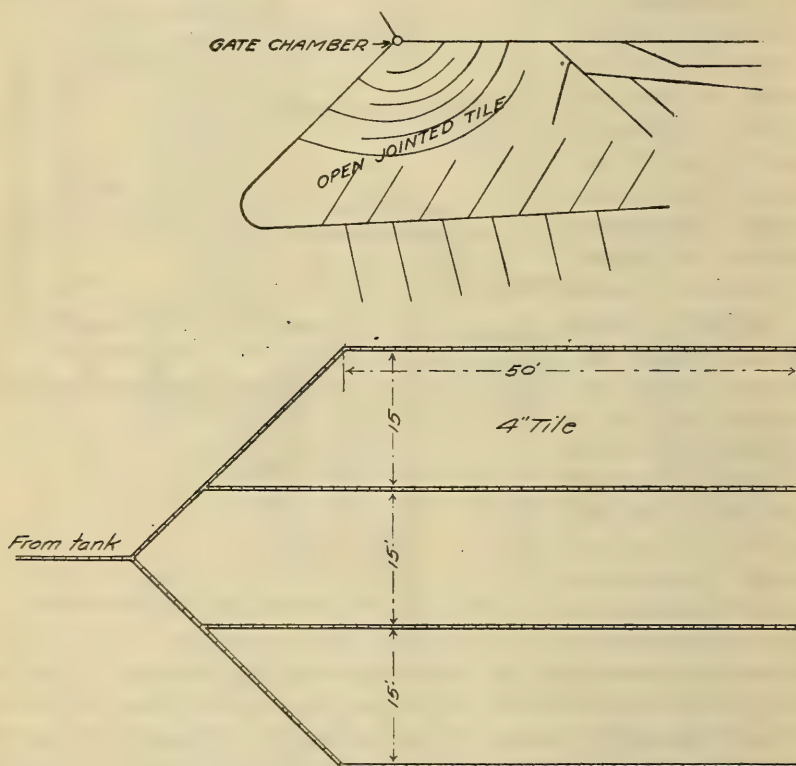


FIG. 32.—Ground plans of tile sewage disposal systems.

THE FINAL DISPOSAL SYSTEM.**DISPOSAL BY SURFACE OR SUBSURFACE DISTRIBUTION.**

Where the soil is porous or sandy and there is plenty of area available which is used for no other purpose, the sewage from the septic tank may be discharged through 4-inch distribution tile laid on the surface of the ground in gridiron or herringbone fashion. Four hundred and fifty to 500 square feet of area are necessary for each person served if the soil is very porous and sandy, and the soil should either be tile-drained or have natural underdrainage.

A better method of disposal is by subsurface distribution. In this method the tile are placed in the ground in herringbone or gridiron fashion, not deeper than 14 or 16 inches from the surface of the soil to the top of the tile. Figure 32 shows ground plans of such systems. In very porous or sandy soils 1 foot of 4-inch tile per gallon of discharge per day is sufficient. In the heavier loam soils 2 feet of 4-inch tile are necessary and sometimes more for every gallon. A rough estimate should be made of the number of gallons of sewage in each discharge from the tank and the number of discharges per day. Not less than 35 feet of 4-inch tile per person should be used in sandy or porous soil and not less than 60 feet per person in very heavy loams. In average loams 300 to 400 feet of tile are sufficient for a family of six or eight.

Aeration of heavy soils can be brought about by the use of coarse cinders or gravel laid in 12-inch to 16-inch layers in the bottom of the tile ditch with the top about 12 inches below the surface. The tile are laid in these at the usual depth. Figure 33 shows such an arrangement.

The disposal tile should have a fall not to exceed 1 inch in 50 feet, else the water will rush to the lower end and water-log the soil there. The tile are usually laid about $\frac{1}{4}$ inch apart and in rows about 15 feet apart. The latter distance, however, will vary with the porosity of the soil. Where there is no subsurface drainage, artificial drainage should be provided by means of tile drains laid below the sewage tile as shown in figure 34. In some cases an impervious stratum underlying the filter earth is underlain by a stratum of sand. Cases have been noted in which this impervious stratum has been broken by dynamite at 15-foot to 20-foot intervals along the tile line, thus providing natural drainage.

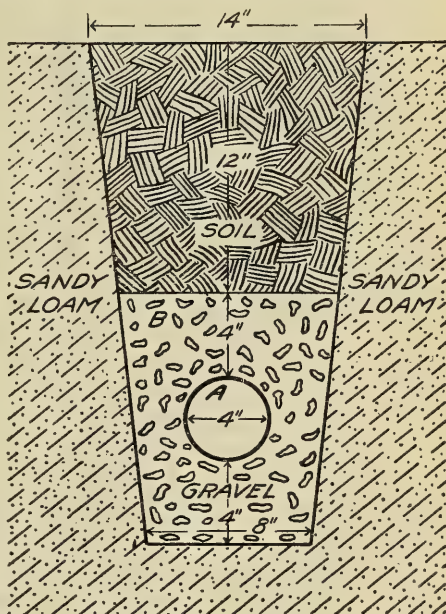


FIG. 33.—Cross section of single tile sewage disposal system, showing method of aerating heavy soils.

DISPOSAL BY INTERMITTENT SAND FILTRATION.

If subsurface disposal is not feasible, for instance when the soil is compact and nearly impervious or is swampy and underdrainage is difficult to obtain, disposal by intermittent sand filtration is necessary.

The sand filter usually is a bed of sand 3 to 4 feet thick which is fine on top and gradually increases in size to coarse gravel at the bottom. The sewage from the tank is distributed over the filter by means of tile laid loose-jointed over the surface in much the same

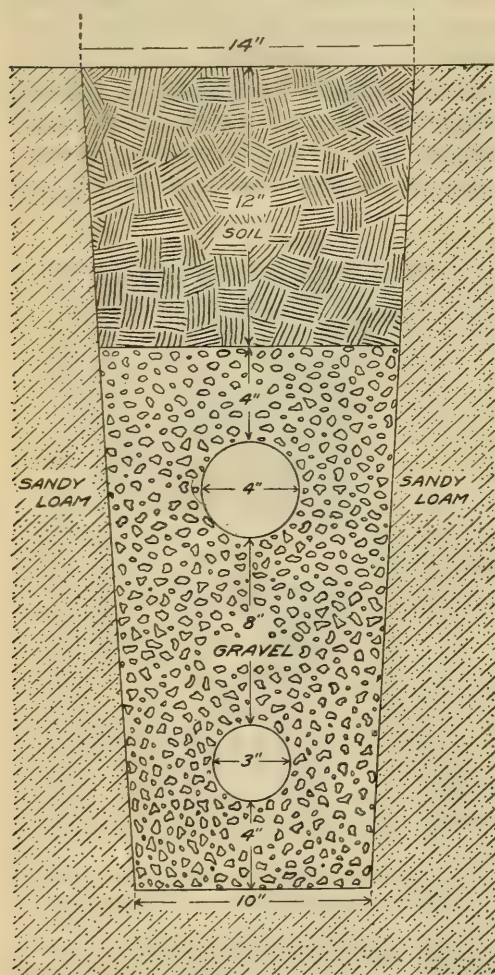


FIG. 34.—Cross section of single tile sewage disposal system, showing second tile below for underdrainage.

manner as in the ground-surface distribution system. The filter should be sufficiently porous and there should be sufficient natural or artificial underdrainage to allow every dose of sewage to sink away rapidly. Sewage should not stand on the surface of the filter for any length of time, as this will soon destroy its purifying properties. About 45 square feet of filter should be provided for each person served by the sewer. The area should be divided into from three to five beds so that each bed may be allowed to rest occasionally. Figure 35 shows a plan and partial section of a sand filter for a family of eight persons.

In constructing a filter a sufficient area should be leveled off and small earth embankments be made 18 inches to 2 feet high to inclose the beds. The depth of the filtering material will depend largely on the porosity of the subsurface

and the means of underdrainage, but it is well to have it not less than $2\frac{1}{2}$ feet; 3 to 5 feet is better, but the depth should not exceed 6 feet. A good plan is to allow a minimum of 1 cubic yard of filtering material for every 50 gallons of sewage flow.

SINGLE-CHAMBER TANK SYSTEMS.

Single-chamber septic-tank systems may be made to give fair satisfaction if properly designed and operated. In such a system the sewage is received, settled, partially purified, and discharged by one chamber.

There is necessarily considerable disturbance of the sewage in the tank, and, in addition, the discharge is continuous. This makes necessary two disposal systems, with a diverting gate to allow an occasional breathing spell for each system. If such an arrangement is not used the disposal system must be of much larger capac-

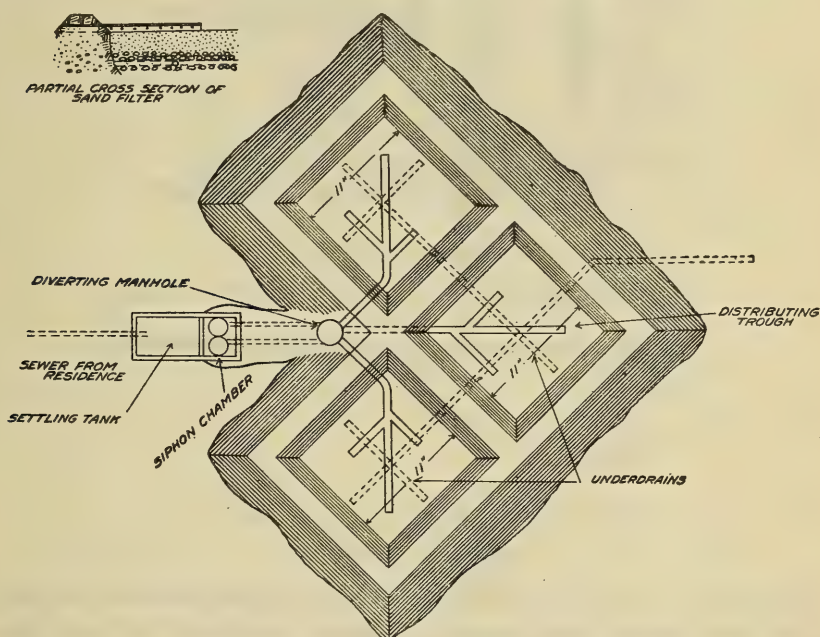


FIG. 35.—Sand filter for eight people.

ity than for the double-chamber tank system, in order to prevent the continuous discharge from waterlogging the system.

If a single-chamber tank is used it should be designed and constructed on the same basis as the settling chamber of a double-chamber tank, with the elbows at inlet and outlet and baffle boards before these openings to break up the current.

Figure 36 shows a single-chamber tank for a family of six. This tank has a continuous discharge, and it is necessary to use a switch or diverting gate, as shown in figure 37, so that the liquid sewage may be intermittently diverted from one part of the disposal system to another.

The disposal system should be divided into at least two divisions for intermittent application, and the capacity of the system should be 10 to 15 per cent larger than for a double-chamber tank system.

The single-chamber septic tank system requires considerable attention, since there is no provision for automatic discharge. Figures taken from the work of the Wisconsin Agricultural Experiment Station show that in the long run there is little difference in the cost of the single and double chamber tank system.¹

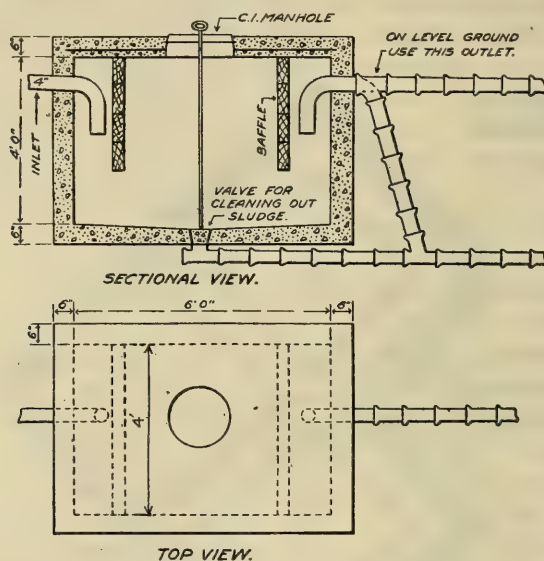


FIG. 36.—Single-chamber septic tank for six people.

THE GREASE TRAP.

The grease trap acts as a separator of the grease and sewage from the kitchen sink or dairy room. If grease is allowed to enter the sewer it accumulates and eventually clogs the system.

Figure 38 shows a grease trap.¹ Two large, glazed sewer tiles are placed in the ground. The inlet is usually a 2-inch iron pipe. The outlet must be so arranged that the mouth of it is at all times below the surface of the sewage. The grease, being lighter, naturally floats upon the water, and is thus prevented from entering the outlet. The outlet is made of 4-inch glazed sewer tile and is connected with the sewer inlet of the septic tank. A concrete cover is provided, and grease and dirt which may accumulate are removed when necessary.

¹ Wisconsin Sta. Circ. Inform. 34.

SUGGESTION ON OPERATION.

Contrary to the usual opinion, small sewage systems require some watching and care. It is well to study the system and watch the action in the entire plant for any signs of clogging or waterlogging. In this way one will soon become acquainted with the conditions of location and soil best suited to his needs and will be able to operate his plant on a satisfactory basis.

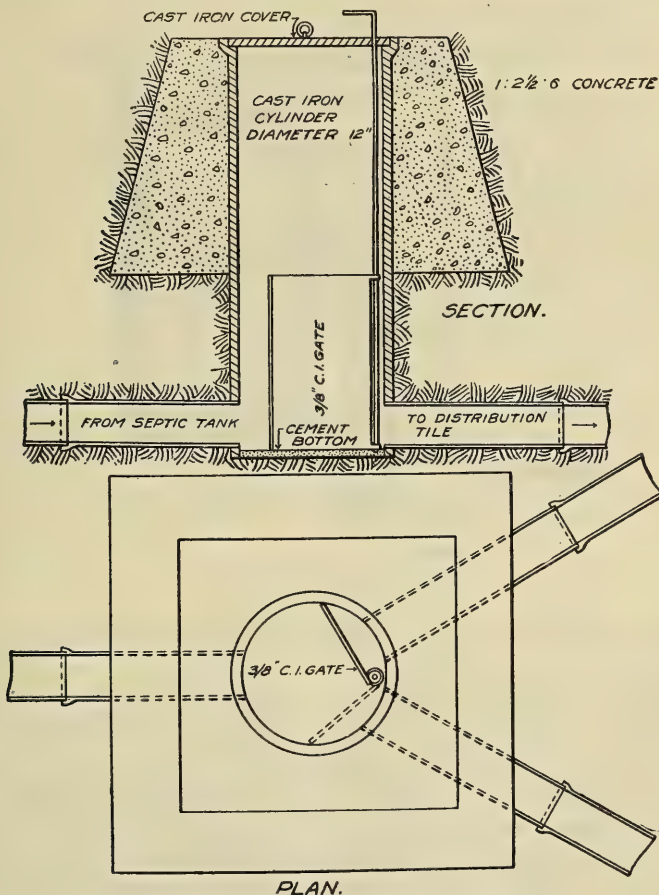


FIG. 37.—Plan and section of sewage diverting gate.

CONCLUSION.

It is hoped that the foregoing discussion has presented information of a nature practical enough at least to indicate the general requirements to be met in planning sanitary systems adapted to the average farm home. Nevertheless, should the farmer feel that, though desirable, such an installation is beyond his own skill, the matter is still of such importance as to make it advisable to employ

a reliable pump expert, plumber, or sanitary engineer, local prices of labor and materials and other conditions permitting. Enormous expenditures are being made by progressive cities in the installation of sanitary systems to protect the health of their people, and similar protection is surely due the country resident. It is urged, therefore, that the questions discussed in this bulletin be considered of prime importance in planning or improving the farm home, instead

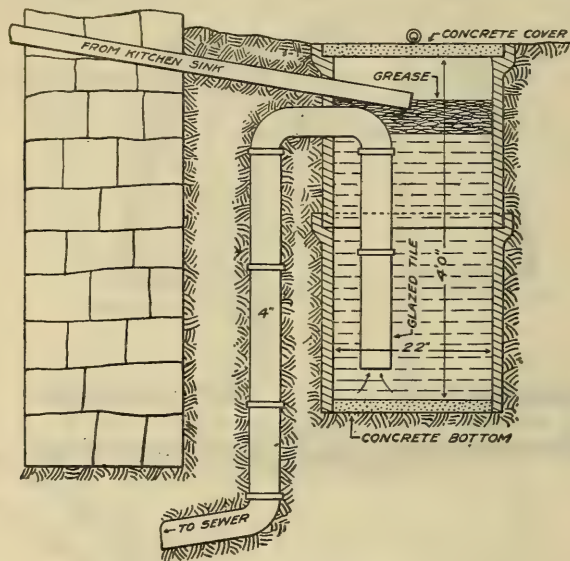


FIG. 38.—Grease trap.

of being postponed to a time when other matters do not press for attention.

No costs of material or labor have been quoted, since these will vary with time and locality. Suffice it to say, however, that nothing has been recommended in this bulletin which is not considered to be an economical investment for any progressive farmer. It is believed that convenience, comfort, and economy may be combined in the practical application of the suggestions made, providing common sense and proper care are exercised in the installation, operation, and maintenance of the conveniences.



BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 58



Contribution from the Bureau of Biological Survey, Henry W. Henshaw, Chief.

February 7, 1914.

FIVE IMPORTANT WILD-DUCK FOODS.

By W. L. McATEE, *Assistant Biologist.*

Numerous requests for Circular No. 81, containing information on the value, appearance, distribution, and propagation of three important wild-duck foods, namely, wild rice, wild celery, and pondweeds, attest the widespread demand for knowledge about plants attractive to wild fowl. The data gathered by the Biological Survey relating to duck-food plants has been widely used by State game commissions, game protective associations, and individuals interested in the protection, preservation, and propagation of our native species of ducks and geese. To make available further information of this nature the present account has been prepared, which treats of five other plants of great intrinsic value. Though at present of local importance, all of them are suitable for propagation over most of the United States, and there is no reason why they should not be introduced and take rank among the staple foods of wild ducks in many localities where now unknown.

DELTA DUCK POTATO.

VALUE AS DUCK FOOD.

In the latter part of January and early February, 1910, the writer, under authorization of the Biological Survey, visited the Mississippi Delta, La. One of the principal objects of this trip was to find out what it is that attracts large numbers of canvasbacks to this shoal-water region, the shallow ponds and lakes of which are so different from the comparatively deep water bodies frequented by canvasbacks in the northern States. The attraction was found to be a species of *Sagittaria* (*S. platyphylla*), which is known to the hunters of this and other parts of Louisiana as wild potato or wild onion. From an examination of a large number of stomachs it was found that about 70 per cent of the food of the canvasbacks collected consisted of the tubers of this plant, as did also more than 65 per cent of the food of the mallards. The pintail also was found to feed upon the tubers. The gullet of one canvasback was filled to the throat with the duck potatoes, 24 entire ones being present, besides ground-up remains of several others. Other individuals had 14 to 17 of the tubers in their gullets. There is no doubt that *Sagittaria platyphylla* is an impor-

tant food for the larger species of ducks not only in the Mississippi Delta but throughout the whole range of the plant.

DESCRIPTION OF PLANT.

The Delta duck potato (fig. 1) when well developed stands about 18 inches above the soil. The broadly elliptical leaves have a char-



FIG. 1.—Delta duck potato. (Scale is 18 inches long.)

acteristic firm appearance and a beautiful clear green color. Like all plants of its genus, this species produces the flowering peduncles from about the center of the group of leafstalks; these peduncles bear

flowers in whorls of three, and the individual flowers each have three white petals and a yellow center. The petals soon fall and the small green balls of immature seeds remain. These enlarge during the summer, and when ripe are brown and nearly half an inch in diameter. They are easily crushed, separating into hundreds of thin triangular seeds.

The tubers are of irregular globular shape and vary up to an inch in diameter. They are formed at the ends of runners (thicker than the roots) and bear on the side opposite the attachment to the runner a scale-sheathed bud which may be an inch or more in length. Run-

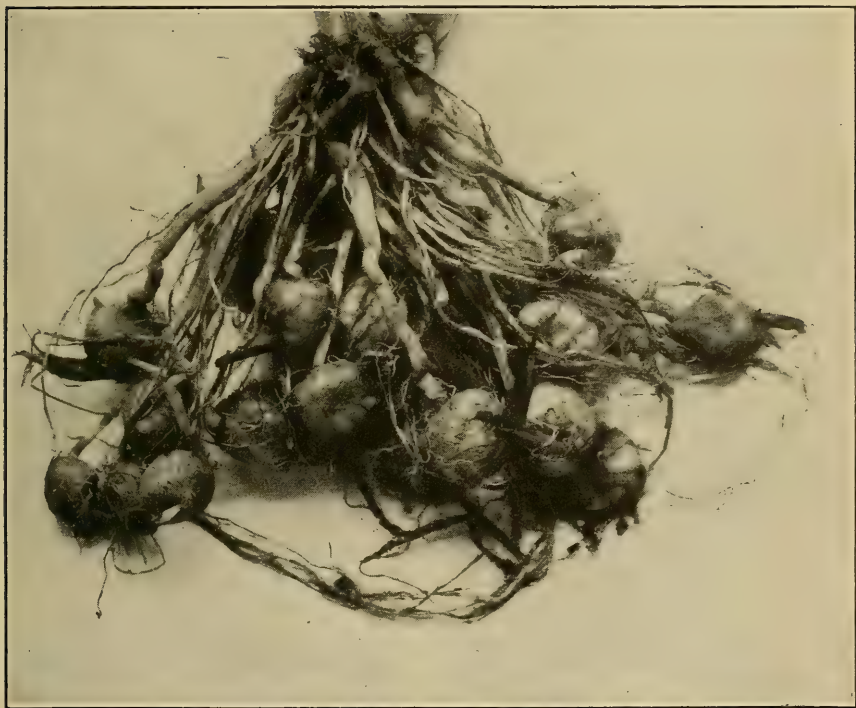


FIG. 2.—Tubers of the delta duck potato. (About two-thirds natural size.)

ning around the body of the tuber are two or three darker lines from which originate fibrous sheaths. A glance at the illustration of the tubers (fig. 2) of this species shows the aptness of the name wild potato. It should be explained, however, that normally the tubers would be more widely separated than is the case with those on this particular specimen, which was grown in a flower pot.

DISTRIBUTION.

In ancient times the Mississippi River emptied into a vast bay which extended at least as far north as the region now known as

southern Illinois. Its actively growing delta (which is still apparently in full vigor) made thick deposits of silt over some thousands of square miles of this area while the remainder was being slowly elevated. *Sagittaria platyphylla* is so nearly confined in its distribution to this ancient basin, and is so characteristic of the present delta, that the name delta duck potato is eminently fitting. The outlying points of the range of the plant as now known are San Antonio, Tex., Lake City, Mo., Chattanooga, Tenn., and Mobile, Ala. (See fig. 3.)

PROPAGATION.

The delta duck potato undoubtedly can be propagated from seed, but all things considered, transplanting the tubers is probably much the better method. This insures a large percentage of success, the

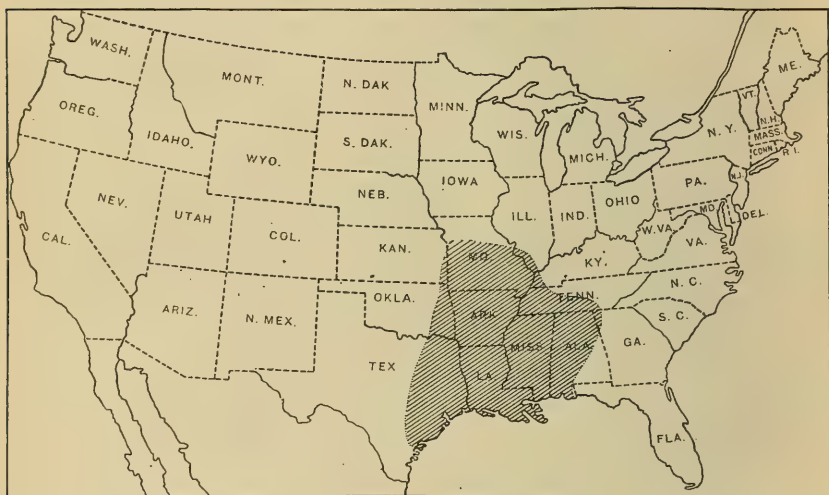


FIG. 3.—Range of the delta duck potato.

plants will be larger, and as they will produce other tubers the first year they are much more valuable. Extraordinary precautions to prevent drying are not necessary, but the tubers should be kept cool and well exposed to the air to prevent heating or fermentation.

To plant, embed the tubers in mud bottom where the water is not more than a foot deep, preferably not more than 6 inches. It is better to err on the shallow side. The plant will grow thriftily on soil never covered by water but which has plenty of moisture. In such situations, however, the tubers are not available to ducks unless overflowed in winter. The delta duck potato is not injured by a slight amount of salt in the soil. The plant is probably hardy anywhere in the southern half of the United States and may prove to be so farther north.

WAPATO.

VALUE AS DUCK FOOD.

The tubers of wapato (*Sagittaria latifolia* and *Sagittaria arifolia*) have been known to white men as an important food for wild fowl since the time of the Lewis and Clark expedition of 1804–1806. These famous explorers state that in the Columbia River Valley large numbers of ducks, geese, and swans occur where this plant is abundant and that the swans in particular feed extensively upon the plant. A correspondent of the Survey, George W. Russell, of Gaston, Oreg., writes that the wapato is fed upon most by the diving ducks, as the canvasback, redhead, and bluebills (scaups), and that they seek it whenever they are present in the country where it grows. Prof. David Dale Owen in his report of a geological survey of Wisconsin, Iowa, and Minnesota notes that these tubers afford much nourishment to the larger aquatic fowls. The vernacular names swan potato and duck potato that have been applied to these plants give further evidence of their value to wild fowl. Other local names are swamp potato, muskrat potato, Chinese onion, and water nut. The Biological



FIG. 4.—Young eastern plant of the wapato with single tuber. (Two-thirds natural size.)

Survey has found various parts of *Sagittaria* plants in stomachs of the following species of waterfowl: Mallard, widgeon, green-winged teal, blue-winged teal, spoonbill, pintail, canvasback, little bluebill, ruddy duck, Canada goose, and whooping swan.

DESCRIPTION OF PLANT.

The general relations of the stems, flowers, and tubers are the same in the wapato (fig. 4) as in the delta duck potato. The shape of the leaves, however, is entirely different. Both *S. latifolia* and *S. arifolia* have arrowhead-shaped leaves. These vary greatly in the length, width, and shape of the point and barbs and in the degree of

divergence of the latter. Various forms of leaves are illustrated by figure 5. The wapato plant sometimes reaches a height of 4 feet. The appearance of the flowers and seed balls is much the same as in the delta duck potato.

The tubers of *S. latifolia* (fig. 6), from six to nine in number per plant, are formed on runners in the same manner as those of the delta duck potato, but they attain a much larger size. The largest specimen examined by the writer is 2 inches in its longest diameter and 1 inch thick. Including the bud and a short stalk at the base, the entire tuber may measure as much as 5 inches in length. The mature tubers of plants from the northwest are more or less flattened, the shape being comparable to that of the ordinary edible crab. The smaller tubers are more nearly spherical (varying to ovoid), and this is the shape of even the largest tubers of eastern plants that the writer has seen. The sheaths of the tuber being of a darker color than the body are conspicuous.



FIG. 5.—Various shapes of wapato leaves. (About one-tenth natural size.)

DISTRIBUTION.

Sagittaria latifolia is found from the Atlantic to the Pacific coast, its range covering practically the whole United States. Areas from which it apparently has not been reported are peninsular Florida, the southern two-thirds of Louisiana and Texas, New Mexico, Arizona, and southern California. The northern limit of its range is marked by the following localities: Vancouver Island, Saskatchewan River, and southern Ontario and Quebec. *Sagittaria arifolia* is confined to States from Michigan and Kansas westward. Its range is largely included in that of *latifolia*, although it has been collected in New Mexico. The two species are only distinguishable with certainty upon the basis of mature seeds, and for all practical purposes may be considered as one. (See fig. 7.)

PROPAGATION.

Wapato may be transplanted by means of both seeds and tubers, but the latter are the most reliable and give the quickest results. They may be set with the bud just beneath the surface in mud bottom under a foot, or preferably less, of water. The plants will grow in

wet soil, but the tubers are not available for duck food in such places unless overflowed in fall and winter.

The tubers of this plant are known to retain their vitality when dried, but more uniform success will probably be had if drying is not

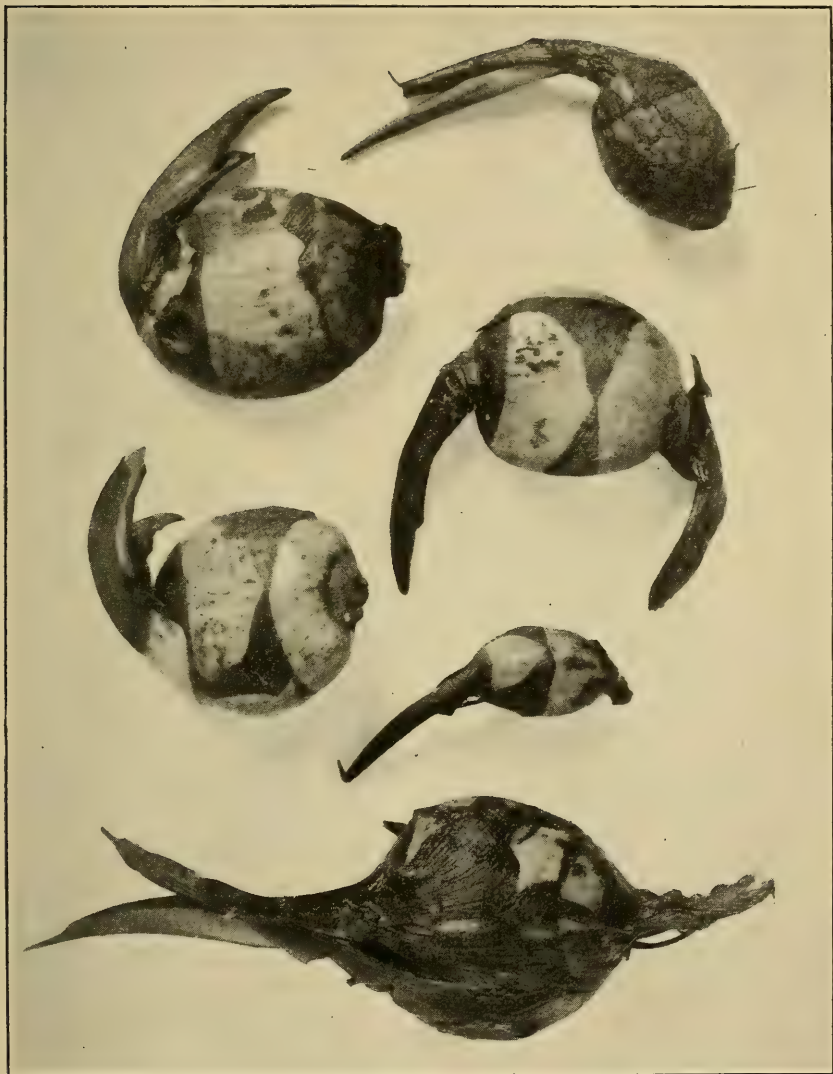


FIG. 6.—Wapato tubers. (About two-thirds natural size.)

carried to an extreme. We recommend that the tubers be shipped promptly after gathering, in well ventilated packages, and that they be planted immediately upon receipt. Wapato is suitable for cultivation in practically all parts of the United States.

CHUFA.

VALUE AS DUCK FOOD.

Like some of the other duck foods mentioned in this circular, chufas are at present known to be of only local importance. Those best acquainted with conditions at Big Lake, Ark., one of the most famous hunting grounds of the South, believe that the chufa, or nut grass, as it is there called, is the principal element in rendering that lake so attractive to waterfowl. Examination of stomachs from that locality seems to justify this belief. Six out of a series of nine mallards collected at Big Lake in December, 1910, had fed on sedge tubers, the average percentage of which in the total food of the nine

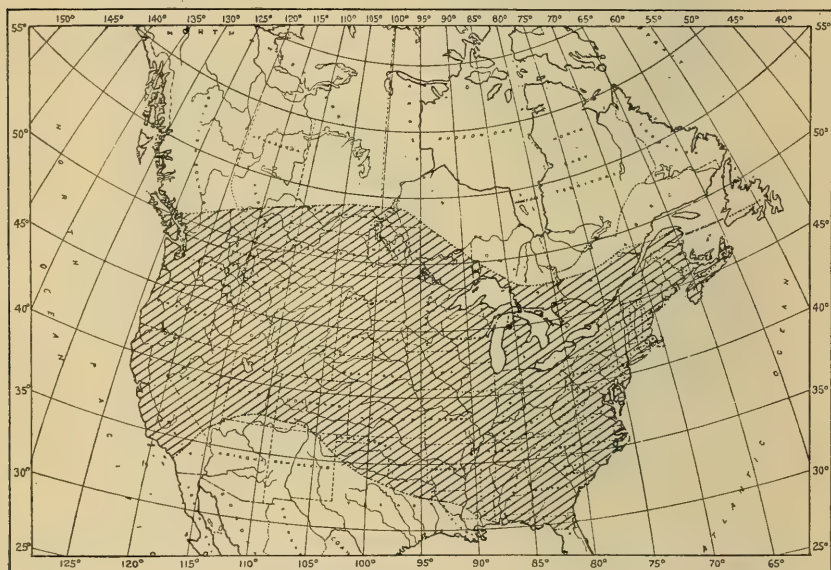


FIG. 7.—Range of the wapato.

was 56. Tubers of this species or others of its genus have been found also in duck stomachs from Florida, Illinois, Minnesota, and California. The species of ducks now known to feed on chufas are the wood duck, mottled duck, mallard, and canvasback.

DESCRIPTION OF PLANT.

The chufa (*Cyperus esculentus*) (fig. 8) belongs to the group of plants known as sedges. These are grass-like and usually classed with the grasses by nonbotanists. Many of the sedges, however, including the chufa, have triangular, not round, stalks. The members of the genus *Cyperus* have a group of leaves at the base from which rises the stalk bearing the flowers and seeds. In the chufa these stalks are from 1 to 3 feet high. Several flower clusters on peduncles of

varying length rise from the top of the stalk. From the same point three rather long grass-like leaves project below the fruiting clusters.

Many members of the genus have a very similar appearance and it is not expected that nonbotanical observers can distinguish them. This is unnecessary, however, as tubers of the chufa for



FIG. 8.—Seed-bearing and immature plants of the chufa. (Much reduced.)

propagation may be obtained from most seedsmen. The tubers of the chufa are formed at the ends of scale-covered rootstocks. The plant is extremely prolific, cultivated forms usually producing 100 tubers to the plant, and instances are known in which more than 600 tubers were produced in one season from one tuber planted in the spring.

Well-developed tubers of the cultivated variety average about three-fourths of an inch in length by three-eighths of an inch in diameter when dried. Tubers from wild plants are usually much smaller and have a greater proportion of fiber. The general appearance of chufas and of tubers from a wild sedge are well shown by figure 9.

Chufas are known also by the vernacular names, earth almonds and ground nuts, and the plant as nut grass and cache-cache.

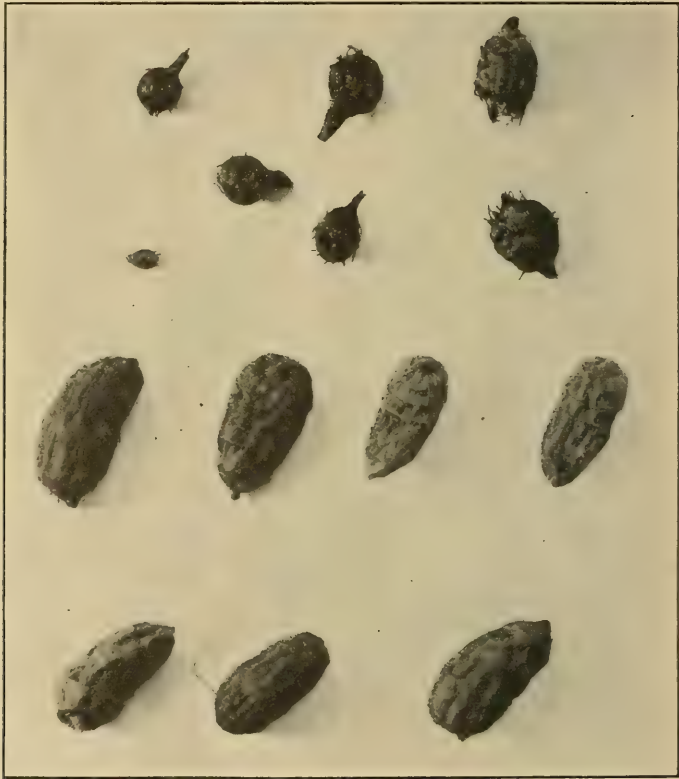


FIG. 9.—Tubers of wild *Cyperus* and cultivated chufas. (Natural size.)

DISTRIBUTION.

The northern boundary of the natural range of the chufa is marked by the following localities: Southern New Brunswick, southern Ontario, northern Nebraska, New Mexico, Arizona, and the Columbia River Valley. The plant seems to be absent from most of the Great Basin and Rocky Mountain regions. From the northern line specified the plant ranges southward over the remainder of the continent. (See fig. 10.) It is widely distributed in warm climates over the entire world.

PROPAGATION.

Although the chufa seems not to grow naturally in a large area in the western United States, there is no doubt that it can be cultivated everywhere except in the higher parts of the Rocky Mountain region. It is said to do fairly well at the altitude of Denver.

Chufas can be obtained from most seedsmen and are so cheap that it will pay sportsmen to buy new stock every few years, if earlier plantings show degeneration in size of the tubers and hence reduction in value as duck food. Chufas do best on light or somewhat sandy but rich soils. They are only available for duck food when planted



FIG. 10.—Range of the chufa.

on land dry in summer and overflowed in winter. In the open they should be planted thickly so as to give the plants a better chance in competition with weeds. In timbered land they need not be planted so thickly, but they will do well only in rather sparse growths, where considerable light penetrates to the ground. When possible the land where planting is intended should be broken up and freed from weeds. Plant the tubers just beneath the surface in spring.

WILD MILLET.

VALUE AS DUCK FOOD.

Wild millet (*Echinochloa crus-galli*) is an important food for ducks in widely separated regions of the United States. At Mud Lake,

Ark., the writer found seeds of this plant to constitute more than 10 per cent of the food of the 41 mallards collected; at Belle Isle, La., it made up more than half of the food of the few mallards examined, and at Cameron, La., over 75 per cent of the diet of a collection of 50 ducks of the same species. Pintails, teal, and other shoal-water ducks are almost equally fond of it. Geese eat the stems and leaves of the plant, as also do ducks when they are hard pressed. Testimony as to the value of the plant has come from Wisconsin and Oregon, and the Biological Survey has found seeds of wild millet in duck stomachs from Massachusetts, South Dakota, Missouri, and Nebraska in addition to the States above mentioned.

The plant is popularly known throughout lower Louisiana as wild rice and is given about the same rank as a duck food as the plant (*Zizania aquatica*) known by that name in the north. Other popular names referring to the preference of wild fowl for the plant are goose grass and blue duck food.

DESCRIPTION OF PLANT.

Wild millet is a coarse, leafy grass which grows from 1 to 6 feet in height. The stems and foliage are not especially remarkable, but the fruiting head has characters which enable us easily to distinguish this from other species of native grasses. The chaff or outer seed coverings is set with rows of short, stiff, outstanding spines. These project beyond the general outline of the body of the seeds and give them an easily visible spiny appearance (fig. 11). The inner scale of the chaff terminates in a spine which is always stouter and longer than the others. This spine or awn may be very short or it may be from 2 to 3 inches long or more, surpassing by many times the length of the seed. One of the other scales also may bear a long spine at the tip. The prickly character of the seed coverings is referred to in the name cockspur grass. The longer awns in particular and sometimes the whole fruiting heads may have a deep purplish color. This, no doubt, suggested the name blue duck food used in the Mississippi Delta. The long-awned form has been given the varietal name *longearistata* but for present purposes we may consider all the types illustrated in figures 11 and 12 under the same name. It is probable also that the form named *Echinochloa walteri* is fully connected with *crus-galli* by intergrades, and deserves only varietal rank. This form has the lower or all leaf sheaths rough hispid.

DISTRIBUTION.

The northern limit of the range of wild millet so far as known to us does not much surpass the latitude of the northern boundary of the United States. From there the plant ranges indefinitely to the southward, occurring generally in rich moist soils or swamps at least to Central America.



FIG. 11.—Part of fruiting head of wild millet. (Natural size.)

PROPAGATION.

Wild millet is easily cultivated and reseeds itself. It requires a moist and preferably a rich soil, such as the edge of a marsh or lake, and it will grow in water at least a foot in depth. Break up the soil (mainly for the purpose of discouraging other plant growth) and sow thickly in spring. Once established, the plant will take care of itself. The nearer to water it is planted the more available it will be for duck food. It is a splendid plant to use for low lands that are flooded in winter.

The seeds are sold by most seedsmen under the name barnyard grass. A variety has been widely advertised as Japanese barnyard



FIG. 12.—Fructing heads of wild millet. (One-third natural size.)

millet or billion-dollar grass. The plant is also known as cockspur grass and sour grass. It may be cultivated in any part of the United States having the proper soil conditions.

BANANA WATER LILY.

VALUE AS DUCK FOOD.

The writer has investigated the value of the banana water lily (*Nymphaea mexicana*) as a food for wild ducks in only one locality—Lake Surprise, Tex. The proofs of its importance are so great, however, that they should be brought to the attention of American sportsmen. At Lake Surprise the banana water lily alone made up

nearly half of the entire food of the 10 vegetarian species of ducks occurring there at the time. This showing is much more significant from the fact that sago pond weed (*Potamogeton pectinatus*) also was abundant in the lake. The latter plant, in the writer's opinion, is the best all-round duck food¹ in North America, yet at Lake Surprise it furnished somewhat less than 29 per cent of the food of the ducks in comparison with more than 48 per cent supplied by *Nymphæa mexicana*.

Thirty-seven canvasbacks collected at Lake Surprise had eaten various parts of this plant to the extent of 71.6 per cent of their diet. This is a second illustration of the unusual phenomenon of the canvasback's being attracted to shallow water by a highly prized food. Six ring-necked ducks or blackjacks made more than 91 per cent of their food of this plant, and two southern black ducks (*Anas fulvigula*) 98 per cent. The parts eaten are the rootstocks, stolons, tubers, and seeds. Mr. Charles W. Ward has sent us rootstocks of *Nymphæa mexicana* from Avery Island, La., with the information that this plant and wild celery (*Vallisneria spiralis*) furnish the bulk of the food of canvasbacks in that locality.

DESCRIPTION OF PLANT.

For the purposes of field identification the water lilies of the United States may be divided primarily into two groups according to the shape of the leaf. Two genera, the water shield (*Brasenia*)² and the American lotus, or water chinkapin (*Nelumbo*),² have entire circular leaves with the leaf stalks attached at their centers. The remaining two genera have more or less heart-shaped leaves or a circular or oval leaf with a cleft or sinus from the edge to the point of attachment of the leaf stalk. Of these two genera, one (*Nuphar*),² including the spatterdocks or toad lilies, has the top or more of the ovary plainly visible when in flower, the other has the ovary practically hidden by the very numerous stamens. To this last group belongs *Nymphæa mexicana*, and it is the only native species of the genus that has yellow flowers.

Both the leaves and flowers of this species may either float on the surface of the water or stand a few inches above it. The leaves are green above with brown mottlings and vary from greenish to purplish red below with small black markings. The edges of the cleft of the leaf are either somewhat separated or overlapping (fig. 13). The plant springs from an upright rootstock (fig. 14) which bears some resemblance to an unopened pine cone. The rootstocks vary in size up to 2 inches in thickness and 12 inches in length. The smaller ones (at least up to 1 $\frac{3}{4}$ inches in length by three-fourths of an inch in thickness) are swallowed by ducks.

¹ See Biological Survey Circular 81, pp. 11-17, for full account.

² The seeds, at least, of all these plants are eaten by many kinds of ducks.

Tender white stolons or runners extend in various directions from the rootstock. These runners are from a quarter to half an inch in diameter. During the active growing season they give rise to new plants, but in autumn they form peculiar hibernating bodies. These consist of the short modified tip of the stolon, which bears several (1-7) upwardly-directed buds on one side and a cluster (2-17) of thick tuberlike roots on the other. The appearance of these (fig. 15) is strongly suggestive of a miniature "hand" of bananas, and for this reason the name banana water lily is proposed for this plant, which

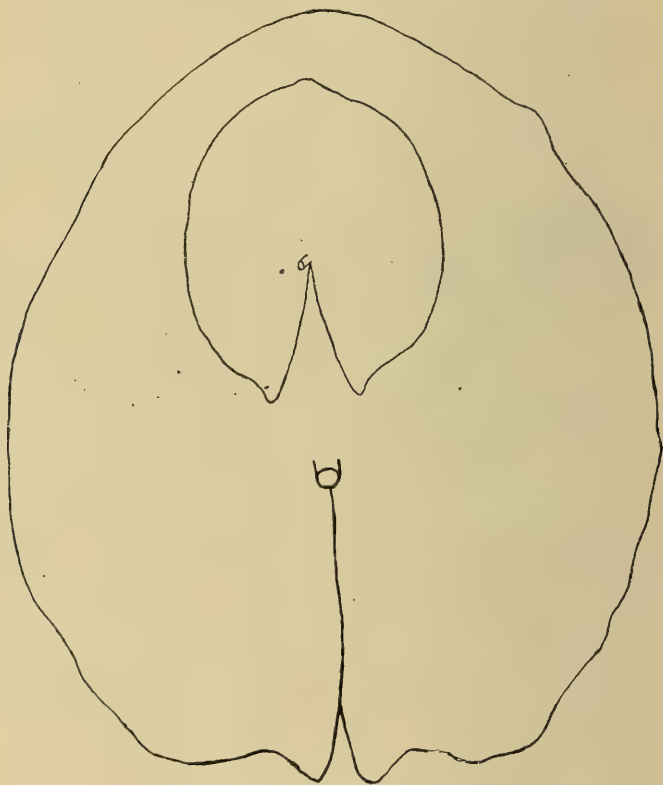


FIG. 13.—Two types of leaves of the banana water lily. (The larger outline half natural size.)

at present has no distinctive vernacular appellation. The name has the additional merit of suggesting the yellow color of the tubers and of the flowers.

DISTRIBUTION.

The banana water lily has been known chiefly as a native of Florida and the plants of that State have long gone under the name *Nymphaea flava*. Plants identified from a few localities in Mexico and from Brownsville, Tex., have been called *N. mexicana*. Dr. H. S. Conard, who has monographed the genus,¹ unites these species, as he

¹ Publication No. 4, Carnegie Institution, 1905.



FIG. 14.—Small rootstocks of the banana water lily. (Natural size.)

is fully justified in doing on the basis of their possession in common of characters unique among water lilies. The new records of the plant from Galveston, Tex., and Avery Island, La., go far toward bridging



FIG. 15.—Hibernating bodies of the banana water lily. (Two-thirds natural size.)

the previous apparent gap in distribution of the plant and to corroborating Dr. Conard's views. The accompanying map (fig. 16) shows the probable natural range of the species.



FIG. 16.—Range of the banana water lily.

PROPAGATION.

Although the banana water lily is native to only a small portion of the United States, it can be successfully grown over practically the whole country. The plant has long been familiar in cultivation and is sold by most dealers in ornamental aquatics. The water lily expert of one of the largest firms in the United States has informed us that

Nymphæa mexicana is perfectly hardy as far north as New York City when covered with a foot of water and he believes that if covered with 2 feet of water it would be hardy at Boston.

The banana water lily needs an abundance of sunlight, water from 1 to 3 feet deep,¹ and a mud bottom. It is not injured by a trace of salt, as is shown by its growing in lakes very near the coast. The rootstocks may be planted by weighting them with stones and dropping where desired. They have great vitality; they may be shipped with only moderate precautions to prevent them from drying, and may be transplanted at almost any time of the year.

¹ When established it will spread to places where the water is even 5 feet deep.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 59



Contribution from the Bureau of Entomology, L. O. Howard, Chief.
January 19, 1914.

(PROFESSIONAL PAPER.)

THE TOBACCO SPLITWORM.

By A. C. MORGAN and S. E. CRUMB,
Of Southern Field Crop Insect Investigations.

INTRODUCTION.

The following account of the tobacco splitworm (*Phthorimaea operculella* Zeller), although not complete, contains data not heretofore published. The life history notes, description of stages, etc., were made by the junior writer. Credit is due the senior writer for the observations made in Florida and for the recommendations under the heading: "Remedial measures."

In California this insect is a serious potato pest, and Dr. F. H. Chittenden¹ reports that in 1912 two growers at El Monte, Cal., lost \$90,000 and \$70,000, respectively, on the crop of that year. Although quite generally distributed over the Southern States, this insect has caused serious loss to tobacco growers in only one locality, viz., Dade City, Fla. The injury at that place was severe in 1906, more severe in 1907, and culminated in 1908 in a conservatively estimated loss of \$150 per acre—a loss totaling \$12,000 for the 80 acres of shade-grown tobacco. The injury since 1908 has been very light, due in part to the early planting and in part to the very careful and very thorough remedial measures employed.

The variation in food habits, which is noted later, had created the suspicion that the form working upon potatoes might be specifically distinct from the one attacking tobacco. During the summer of 1913 experiments were conducted to determine this point.

EXPERIMENTS ON THE SPECIFIC STATUS OF THE TWO FORMS.

The potato-tuber moths used in these experiments were of the habitual potato-feeding type from Whittier, Cal., kindly furnished by Mr. J. E. Graf. The splitworm moths were of the habitual tobacco-feeding type from Florida, North Carolina, and Virginia.

¹ Chittenden, F. H., 1912. The potato-tuber moth. A preliminary account. (*Phthorimaea operculella* Zell.). U. S. Dept. Agr., Bur. Ent., Circ. 162, p. 2. Chittenden, F. H., 1913. The potato-tuber moth. U. S. Dept. Agr., Farmers' Bul. 557, p. 2.

Larvæ of the potato-tuber moth were reared on potato tubers and on the foliage of *Solanum carolinense*, eggplant, *Physalis* sp., *Datura stramonium* ("jimsonweed"), and tobacco; they also mined the leaves of *Solanum nigrum* until the plant died. Larvæ of the tobacco splitworm moth were reared on potato tubers and on the foliage of *Solanum carolinense*, eggplant, *Physalis* sp., *Physalodes physalodes*, *Datura stramonium*, and tobacco. There was no perceptible difference in the period of development, in habits, or in behavior of the two forms on a given food plant that could be ascribed to the different origins of the individuals. A male potato-tuber moth of the habitual potato-feeding type and a female splitworm moth of the habitual tobacco-feeding type, reared from isolated pupæ and caged together, produced larvæ that reached maturity upon tobacco.

The earliest stages of the two types show no appreciable differences except in the case of the larva, and here the differences, excepting size, are entirely colorational. The larva on potato is larger, grayish, and has the mesothorax and metathorax pinkish, while the habitual tobacco feeder is green and has the mesothorax and metathorax deep maroon. By reversing the two food plants the larvæ can be made to approach each other in coloration, but even after two generations on tobacco the habitual potato feeder is less green and has the thorax distinctly paler than the habitual tobacco feeder; also, the coloration of the latter type persists when reared upon potato tubers. The larvæ of the crossed moths were intermediate in coloration between the two types just discussed.

The rather persistent color variation noted in the two larval types under discussion, while probably of sufficient constancy to warrant a varietal separation, is not, the writers believe, of sufficient importance to justify a specific separation.

Potato-tuber moths reared from potato are usually somewhat larger than splitworm moths reared from tobacco. This difference disappears when the potato-tuber moth is reared on other plants. Potato-tuber moths reared from potato tubers, *Physalis* sp., *Solanum carolinense*, tobacco, and *Datura stramonium*, and splitworm moths reared from tobacco, potato tubers, and *Physalis* sp., were submitted to Mr. August Busck, who reported that he could find no specific differences.

DISTRIBUTION.

In the United States the species occurs in California and southward from a line connecting the District of Columbia and Colorado. The definite localities include Tennessee, Virginia, North Carolina, South Carolina, Florida, and Texas. Reports of more northern occurrence are probably due to the shipment of infested potatoes into these

localities. The known range also includes Cuba, Costa Rica, Peru, Hawaii, Australia, Tasmania, New Zealand, Sumatra, Transvaal, Algeria, and southern Europe.

COMMON NAMES.

Phthorimaea operculella when working upon tobacco is known as the tobacco splitworm and the tobacco leaf-miner; when working upon potatoes it is known as the potato-tuber moth and the potato moth.

FOOD PLANTS.

The known food plants of *Phthorimaea operculella* include *Solanum torvum*, *S. verbascifolium*, *S. carolinense*, *S. nigrum*(?), eggplant, potato, tomato, *Physalis peruviana*, *Physalis* sp., *Physalodes physalodes*, *Datura stramonium*, and tobacco.

FOOD HABITS.

The larva occurs as a borer and also as a leaf-miner. The former is probably the original habit, examples of which have been observed by Quaintance in the fruit of eggplant, by Kotinsky in tomatoes, and by C. W. Howard and Oliff in the stems of tobacco. Dr. L. R. De Bussy considers this the more common form of injury to tobacco in Sumatra, where the larva forms a gall in the stem. C. W. Howard reports a similar habit of the larva in the Transvaal.¹

In Cuba and the United States the insect is known on tobacco as a leaf-miner only. A boring tendency is still apparent, however, as noted by Houser, in that the larva usually tunnels the midrib or a vein in addition to mining the membrane of the leaf. In about 50 mines examined by us the larva had also tunneled the midrib or a vein in almost every case.

Only the older tobacco leaves are affected, unless the infestation is very severe; and in these, the lower leaves, grayish, irregular blotches are produced, which later turn brown and become fragile, so that the tobacco is unfit for wrappers. At Clarksville, Tenn., where the infestation is very slight, the larva in most cases begins work in the "ruffles" along the midrib and may afterward migrate and form mines in various parts of the leaf.

In forming its mine the larva begins by spinning a tent of silk between the midrib, or between the vein and the surface of the leaf. Under this protection it soon forms a shelter between the leaf surfaces by consuming the parenchyma. The mined leaf becomes more or less distorted, and this is especially noticeable on leaves,

¹ *Gnorimoschema heliopa* Low causes similar injury to tobacco in India, Ceylon, and Java.

such as those of *Solanum carolinense*, which the larva is more capable of manipulating, but there is no tendency to form a firm, cylindrical, silk-lined tube, as is the case with the blue or bluish-green larva of *Phthorimaea glochinella* Zell., which feeds upon some of the same plants as does *Phthorimaea operculella*.

DESCRIPTION OF STAGES.

THE EGG.

The egg is pale, translucent, yellowish gray, and strongly iridescent; it is oval, 0.45 mm. long, 0.35 mm. broad at the middle, membranous, and without apparent sculpture. The side upon which it is deposited is slightly flattened.

THE LARVA.

The full-grown larva is 7 to 14 mm. long. The head shield is 0.80 to 0.86 mm. broad and fuscous brown. The cervical shield is darker brownish fuscous, with a pale mid-dorsal line, shining, the posterior margin medially straight. The anal shield is brown. The mesothorax and metathorax are deep maroon. The body varies in color through green and gray and is overlaid dorsally with purplish as the larva nears pupation. It is slender, tapering from the mesothorax posteriorly and set closely and uniformly with minute granules each bearing a minute point, the granules of the thorax and the last abdominal segment being the larger. The tubercles and their setæ are inconspicuous, brownish; tubercle II is slightly larger than I. The legs are deep fuscous; the prolegs, green.

The larva which has just emerged is light grayish, with strongly contrasting dark head and cervical shield.

Larvæ which have been reared habitually upon potatoes are of a larger average size than those reared upon tobacco, and the maximums of the foregoing measurements are from potato-feeding larvæ. The larva on potato is more grayish on the body than the tobacco miner and has the mesothorax and metathorax pinkish instead of deep maroon.

THE PUPA.

The pupa is yellowish brown, 5.5 to 7 mm. long and 1.5 to 2 mm. broad; it is broadest through the metathorax, tapering both anteriorly and posteriorly. The head is rather distinct and slightly nodding. The abdomen, excepting the last three segments, is set with very minute spinules; it bears at the tip mid-dorsally a short, curved, erect, pointed horn flanked by about four pairs of long hooked spinules, and ventrally a pair of blunt, rounded lobes beneath which are about four pairs of long hooked spinules. Each abdominal segment is set with a transverse row of spinules near the anterior margin.

As in the case of the larvæ, the pupæ of the habitual potato feeder are larger than those from the habitual tobacco feeder and the maximum measurements in the foregoing description are from potato-reared pupæ.

The adult is a slender, inconspicuous moth with dark grayish wings bearing indefinite yellowish streaks and having an expanse of about 20 mm.

LIFE HISTORY.

At Clarksville, Tenn., the splitworm requires 25 to 30 days in summer for completing its development from egg to adult. Of this time 4 days are spent in the egg stage, 15 to 17 days in the larval stage, and 6 to 9 days in the pupal stage. The length of these stages is considerably affected by temperature, as is indicated in detail in the accompanying tables. By reference to Table III we see that at an average mean temperature of about 81° to 82° F. the minimum pupal period is obtained, and that when the average mean temperature falls below about 68° to 70° F. the pupal period is very greatly lengthened.

Eggs are deposited singly upon the foliage of the host plant. Moths begin to oviposit two or three days after emergence and continue ovipositing for several nights. The largest number of eggs obtained from a single moth was 46, but this probably does not represent the maximum oviposition under normal conditions.

The larva is very active, is capable of prolonged exertion immediately after hatching, and clings very tenaciously to the foliage. The frass is either stored in a particular part of the mine or is cast outside where, in the case of those working upon potato tubers, it forms masses held together by silk. The larva pupates in a slight but somewhat tough cocoon of silk and débris among clods or rubbish at or near the surface of the soil.

TABLE I.—*Length of egg stage of tobacco splitworm.*

Eggs deposited night of—	Eggs hatched night of—	Egg stage.	Average mean tempera- ture.
		<i>Days.</i>	<i>° F.</i>
June 15, 1910	June 19, 1910	4	77.3
June 17, 1910	June 21, 1910	4	79.5
June 22, 1910	June 27, 1910	5	80.5
July 3, 1913	July 7, 1913	4	82
July 3, 1913	July 7, 1913	4	82
July 4, 1913	July 8, 1913	4	80.9
July 5, 1913	July 9, 1913	4	79.7
Aug. 5, 1913	Aug. 8, 1913	3	88.6
Aug. 6, 1913	¹ Aug. 10, 1913	3½	88
Aug. 21, 1913	Aug. 25, 1913	4	72.6
Sept. 11, 1913	Sept. 15, 1913	4	81.9
Sept. 12, 1913	Sept. 16, 1913	4	82.4

¹ Forenoon.

TABLE II.—*Length of larval stage of tobacco splitworm.*

Egg hatched night of—	Larva pu- pated night of—	Larval stage.	Average mean tempera- ture.	Food plant.
		<i>Days.</i>	<i>° F.</i>	
June 21, 1910	July 6, 1910	15	78.7	Tobacco.
July 9, 1913	July 25, 1913	16	81.1	Do.
Aug. 25, 1913	Sept. 10, 1913	16	81.2	Do.
Aug. 25, 1913	Sept. 11, 1913	17	81.1	Do.
Sept. 27, 1911	Nov. 3, 1913	37	64.4	Do.

The lengths of the larval stage given above are corroborated by about 25 records giving the combined length of the larval and pupal stages.

TABLE III.—*Length of pupal stage of the tobacco splitworm.*

Number of indi- viduals.	Larva pupated night of—	Moth emerged night of—	Pupal stage.	Average mean tempera- ture.	Food plant of larva.
			<i>Days.</i>	<i>° F.</i>	
2	Apr. 21, 1909	May 14, 1909	23	65.1	Tobacco.
4	May 22, 1910	June 5, 1910	14	67—	Do.
1	July 6, 1910	July 14, 1910	8	83.3	Do.
1	July 25, 1913	Aug. 1, 1913	7	85.1	
¹ 3	Aug. 19, 1913	Aug. 28, 1913	9	77.1	Potato.
1	do.....	do.....	9	77.1	"Jimsonweed."
1	do.....	Aug. 29, 1913	10	77.5	Potato.
¹ 1	Aug. 21, 1913	Aug. 30, 1913 ³	8.5	76.4	Tobacco.
1	Aug. 27, 1911	Sept. 8, 1911	12	76.8	Do.
1	Aug. 31, 1913	Sept. 6, 1913	6	83.7	Do.
2	do.....	do ³	5.5	83.7	Do.
1	do.....	do ⁴	6—	83.7	Do.
3	Sept. 1, 1913	Sept. 7, 1913	6	83.7	Do.
1	do.....	Sept. 8, 1913	7	83.2	Do.
1	Sept. 2, 1913	Sept. 9, 1913	7	81.8	Do.
1	Sept. 3, 1913	do.....	6	81.4	Do.
1	do ²	do.....	7	81.4	Do.
3	do.....	Sept. 10, 1913	7	81	Do.
2	Sept. 10, 1913	Sept. 23, 1913	13	69	Potato.
1	do.....	Sept. 24, 1913	14	69.1	Do.
1	Sept. 11, 1913	Sept. 27, 1913	16	68—	Tobacco.
2	Sept. 13, 1913	Sept. 29, 1913	16	67.6	Do.
1	Sept. 27, 1913	Oct. 9, 1913	12	70.4	Do.
1	Sept. 30, 1913	Oct. 15, 1913 ⁴	15	68.3	Physalis.
1	Oct. 1, 1913	do ⁴	14	68.3	Do.

¹ Reared from moths of the habitual potato-feeding type.

² Forenoon.

³ 2 p. m.

⁴ Afternoon.

SEASONAL HISTORY.

Full-grown larvæ have been received from Florida in late April, indicating that oviposition may begin in that region as early as March. Larvæ have not been found at Clarksville, Tenn., earlier than June 3, and moths have emerged in numbers as late as the middle of November. It seems probable that at least six generations are produced in Florida and that about three or four are produced at Clarksville, Tenn. Moths emerged in five cages at Clarksville November 14, 1913, and were still active December 15, 1913, upon which date about an equal number of cages still contained pupæ. These records seem to indicate that the winter is passed in both the pupal and adult stages. No larvæ, so far as known, have entered hibernation successfully.

PARASITES.

Kotinsky¹ records two larval parasites, *Chelonus blackburni* Cam. and *Limnerium polymesiale* Cam. About 25 per cent of the full-grown larvæ of a large shipment of splitworms, sent by Mr. G. A. Runner late in August, 1913, from Kinston, N. C., were parasitized. Several parasitic larvæ emerged from each splitworm which was killed at or just before the emergence of the parasite, and while still in the mine. The parasites spun their cocoons in the mine and sometimes within the larval skin. A single splitworm from which this parasite was reared was included in another large shipment of material sent by Mr. Runner from Appomattox, Va. Larvæ of this parasite which emerged from the host September 1, 1913, pupated September 3, and the adults emerged September 10, giving a pupal stage of seven days.

REMEDIAL MEASURES.

Quaintance² recommends the destruction of the larvæ in the mines by pinching, and the destruction of all trash in and around tobacco fields and tobacco barns. Both of these recommendations should be followed. However, in severe infestations it may be necessary to prime off and destroy the leaves infested by the earlier generations. A heavy infestation would ruin the leaves for wrappers, in which case the priming and destruction of the leaves will be a cheaper and more thorough method of destruction, for it will cause the death not only of the larvæ but also of a large number of eggs. This plan was pursued at Dade City, Fla., following the severe infestation of 1908, and with excellent results. Since that year, also, the crop has been transplanted much earlier than was the custom previously, and was matured before the appearance of the most destructive generation of the splitworm. Loss has been very light since 1908.

To summarize the remedial recommendations: (1) Transplant the crop as early as possible, in order to mature it before the appearance of the most destructive generation of the splitworm; (2) when the early infestation is very severe, prime off and destroy the infested leaves; (3) destroy all tobacco stubble as soon as the crop is harvested to prevent the breeding of a hibernating generation; (4) clean up and destroy all trash in and around tobacco fields and tobacco barns; (5) do not follow potatoes by tobacco, for the infestation of tobacco has been more severe in such cases than where a different rotation was followed; (6) grow potatoes as far as possible from tobacco fields.

¹ Kotinsky, Jacob, 1906. Hawaii. Forester and Agr., v. 3, no. 7, p. 200-201.

² Quaintance, A. L., 1898. The tobacco leaf-miner (*Gelechia picipellis* Zett.). Fla. Agr. Exp. Sta., Bul 48, p. 178-181.





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THE RELATION OF COTTON BUYING TO COTTON GROWING.

By O. F. COOK,

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INTRODUCTION.

The need of closer contacts between the manufacturer who uses cotton and the farmer who produces the raw materials has been recognized in a recent circular on "Factors Affecting the Production of Long-Staple Cotton."¹ It is desirable to go somewhat more fully into this relation, in the hope of making clear to the manufacturer, as well as to the farmer, the fact that the present methods of buying cotton do not contribute to the improvement of the cotton crop, but tend rather to discourage the planting of better varieties and to the neglect of the precautions that are necessary to produce superior fiber. The farmer who produces better cotton than his neighbors needs to understand why it is often difficult to secure a better price.² And at the same time the manufacturer should understand the need of greater discrimination in prices, as the best means of encouraging the production of superior fiber. The greatest improvements in production are to be expected in communities organized to grow commercial quantities of the same variety of cotton. The mutual interest of the farmers and the manufacturers lies in this direction of organized production.

Manufacturers who use long-staple cotton, both in the United States and abroad, have complained of deterioration in quality and diminished supplies of the raw materials, and have believed that their branch of the cotton industry was threatened by agricultural dangers over which they had no control. In reality, there is no agricultural reason why long-staple cottons should not be produced in the United States in much larger quantities than at present and

¹ U. S. Department of Agriculture, Bureau of Plant Industry, Circular 123, p. 3-9, 1913.

² Similar conditions exist with reference to the better grades of short-staple cotton. A discussion of the methods and practices prevailing in the western end of the cotton belt is presented by W. A. Sherman, Fred Taylor, and C. J. Brand, of the Office of Markets, in their Studies of primary cotton market conditions in Oklahoma. (U. S. Department of Agriculture, Bulletin 36, 36 p., 1913.)

also of better quality. These possibilities have had abundant demonstration in many districts of the cotton belt, as well as in the newly settled irrigated regions of the Southwest. It now rests largely with the commercial world of manufacturers and the buyers to determine what kind of fiber the farmer shall produce.

The fear that the boll weevil will put an end to the production of long-staple cotton in the United States may be dismissed. The development of new, early-maturing varieties and the discovery of improved cultural methods for shortening the growing season are making it possible to produce excellent crops of long-staple cotton in the presence of the boll weevil. Indeed, in the presence of the weevil there are additional reasons for growing long staples instead of short staples. The extra care and precautions that are required to protect the cotton against the weevil make it possible to produce a better staple. Thus the growing of long-staple cotton, to sell at a higher price, may be considered as a means of securing a return for the increased cost of production or the diminished yield that may be caused by the boll weevil.¹

THE NEED OF DISCRIMINATION IN BUYING.

With the solution of the biological and agricultural problems of cotton improvement, it has become evident that another class of problems must be solved before any complete development of our resources of cotton production can be expected. These problems may be approached from the commercial side, as they are closely involved with the handling and marketing of the crop, but they have also a very important agricultural bearing that needs to be recognized in planning improvements of commercial conditions. Greater discrimination must be used in the buying of cotton before the farmers will put forth their best efforts toward the development of a new long-staple industry in the United States.

Discoveries that have been made in the investigation of problems of acclimatization and breeding can be applied in commerce as well as in agriculture. Indeed, the commercial applications are likely to determine the extent of the agricultural utilization of the superior varieties that have been developed by acclimatization and breeding.

The selection, or "roguing," that is necessary to maintain the purity and uniformity of varieties can be done much more easily and effectively by taking out the inferior plants early in the season. This not only improves the quality of the seed but also renders the fiber more uniform and more valuable for manufacturing purposes. The same method of field inspection can be used by the buyer to determine the quality of cotton that any field will produce, not only before it is picked, but even before the bolls are set. If selection has been

¹ Cook, O. F. Cotton improvement under weevil conditions. U. S. Department of Agriculture, Farmers' Bulletin 501, 22 p., 1912.

neglected or admixture with other varieties has taken place, the inferior plants can be seen and counted, and different fields can be graded on a percentage basis. Buying cotton in the bale is a mere game of chance compared with what buyers might do in the way of accurate classification if they began with the cotton in the field.

Of course, a system of judging cotton in the field would be very difficult to apply to the cotton industry in its present unorganized condition, with each farmer of a neighborhood likely to grow a different kind of cotton. One of the chief objects to be gained by better methods of buying would be to develop a better system of production, in which the same kind of cotton would be grown throughout a whole community or district. Many advantages, commercial and agricultural alike, would be gained if cotton production were organized on a community basis.¹

That the present system of buying is seriously defective is now widely recognized, and radical reforms are being sought through legislation and otherwise. But it is highly desirable that reforms in the commercial world be considered in their relation to the improvement of the quality of the crop and not merely to secure higher prices for inferior cotton. There is no prospect that such prices can be maintained by any action that may be taken in the United States. The only secure basis for our cotton industry is in the improvement of the product. Otherwise, we remain exposed to the danger of foreign competition. It is much more important to improve the quality of our cotton crop than to secure high prices without such improvement, since high prices for inferior cotton will only stimulate the rapidly increasing production of low-grade cotton in other parts of the world.

VARIETIES DETERIORATE BY LOSING UNIFORMITY.

The fundamental agricultural improvement that requires commercial cooperation is the preservation of superior varieties, so that a uniform product can be obtained. For manufacturing purposes, uniformity is an even more important quality than length of staple and one that must be guarded continually in the production of long-staple cotton. It is much easier to breed new varieties than it is to keep them pure and uniform after they have passed out of the hands of the breeder into the field of commercial production.

The causes of deterioration must be understood before we can appreciate the precautions that have to be taken to preserve superior varieties. There is a misleading popular idea that varieties of cotton are bound to deteriorate and that new seed must be planted every few years in order to maintain the crop. Before the art of antiseptic surgery was known, inflammation and suppuration of wounds were

¹ Cook, O. F. Cotton improvement on a community basis. Yearbook, U. S. Department of Agriculture, 1911, p. 397-410. 1912.

Brand, C. J. Improved methods of handling and marketing cotton. Yearbook, U. S. Department of Agriculture, 1912, p. 443-462, pl. 53-56. 1913.

considered inevitable. The deterioration of cotton varieties is often thought of in a similar way, as something that is sure to occur in a few years. But such deterioration can be avoided just as definitely as wounds can be protected from infection.

The most frequent source of the infection that causes a variety of cotton to degenerate is mixture of seed or crossing with other varieties. The planting of different varieties close together and the exchange of seed at the gin are the usual causes of contamination. The present system of public gins might be described as an unconscious conspiracy to destroy the purity of varieties and does millions of dollars' worth of unrecognized damage in this way every year. The machinery of the gin is arranged to hold a bushel or more of the seed of each customer and to mix it into the seed of the next farmer in the line. No farmer can keep his variety pure who allows a public gin to handle his seed in the usual way. To keep his variety pure, a farmer must either have his own gin or he must find a public gin where he is allowed to clean the machinery and thus keep his seed from being mixed. Very few farmers think of taking such precautions. They prefer to believe, as a correspondent recently assured us, that "what little gets in at the gin will not do any harm."

When mixture with other kinds of cotton is avoided, it is still possible for a variety to degenerate, in the sense of losing its uniformity, unless care be taken to recognize and remove the "sports" or aberrant plants that continue to appear in even the most carefully selected stocks. To rogue out these degenerate plants is as necessary as to prevent mixing with other varieties. The degenerate individuals are like so many different varieties, for the characters of many of them "come true" when the seeds of such plants are saved and planted separately. It is only by observing these two precautions of avoiding admixture and roguing out the "freaks" or "sports" as they appear that varieties are kept from deterioration and made to serve the purposes of production for many years.

After a discovery like antiseptic surgery has been made it seems altogether unreasonable that people should disregard it, at the risk of pain or even death. But it is the lesson of history that reforms come slowly, and the improvement of the cotton industry is likely to follow this rule. It is only when we undertake to avoid infection or contamination that we learn how difficult it is to do so. Even after the farmer understands the importance of maintaining a pure stock of seed there are many ways to bring in contamination, and some of the most intelligent and efficient farmers often make fatal mistakes in their first efforts to maintain a pure stock of seed. The most disappointing cases are those where some accident or error occurs after most of the precautions have been taken. It is not until the farmer learns to think, as it were, in terms of pure seed that he is able to guard himself all along the line of possible errors.

CAREFUL FARMERS DESERVE THE HIGHER PRICES.

No complete or permanent improvement is to be expected unless more direct financial advantages are offered to the careful farmer. The scientific and moral encouragement to raise pure, uniform, high-grade cotton so as to enhance the reputation of the district may be urged as a motive of local patriotism, and local agencies may continue to cooperate in the effort to organize the whole community in the interest of long-staple production, but all these considerations may fail of the desired result unless the commercial interests will add a financial object to the other motives.

As a means of illustrating this, it may be well to give extracts from a report by Mr. Argyle McLachlan, of this department, covering the different kinds of mistakes or accidents encountered in a single season in the effort to guard the Durango cotton against contamination from the Upland short-staple and Egyptian cotton previously grown in the Imperial Valley of California. In addition to placing the farmers more on their guard, an account of these errors may make it easier for manufacturers to understand not only that special precautions are necessary, but that the regular observance of such precautions amounts to a real reform of agricultural methods, a reform that needs to be encouraged by a change of commercial policy.

If any single precaution were sufficient to keep the seed pure, a general observance would be much more easily established, but in reality many different precautions must be taken. Most farmers are now so careless or so little intent upon the idea of keeping their seed pure that they fall readily into one or another of the many mistakes that are fatal to the uniformity of a variety of cotton.

Mr. McLachlan's statement is as follows:

That intelligent management is required to preserve clean stocks of any variety of cotton seed is forcibly shown by the numerous accidents which have occurred in the Imperial Valley in connection with the Durango cotton.

Clean Durango seed, purchased at fancy prices, has been planted on land where short-staple cotton was grown in the previous season, thus insuring mixture of seed and cross-pollination from the volunteer short-staple plants. In one case a farmer who had been cautioned against planting his new pure seed on land where Egyptian cotton had previously been grown, afterward planted the seed on land which had been in short staple. This shows that the object of the precaution was completely misunderstood, for if new land could not be had it would have been much better to plant the Durango where the Egyptian cotton had been. Egyptian volunteer plants could have been detected and removed much more easily than the short-staple Upland volunteers.

Several lots of Durango seed were brought in from Texas, and came from as many different planters. Some lots were known to have been carefully grown and ginned separately to avoid mixing with seed of other varieties, but other lots were not known to have received similar care. Special care had been urged in handling these different lots in order to keep the seed that was known to be clean separate from the other lots. In spite of repeated cautioning, the identity of the clean seed was made uncertain

by failure to mark the bags or to keep them separate. The different lots were piled in the same warehouse and some of the piles fell down.

In one instance, at least, seed of another variety had been distributed as Durango on the careless assumption that all kinds of long-staple cotton were much the same, so that a substitution would be only a mild form of deception. The seed used in this instance to replace Durango was of an inferior mixed stock and would give a very misleading idea of the variety.

Unmixed Durango cotton raised in the Imperial Valley was sent to the public gin and the seed allowed to pass through the conveyors which had been used with short-staple cotton and contained a quantity of the short-staple seed. An appreciable mixture with the short-staple cotton, in some fields from 4 to 6 per cent, occurred in this manner.

Admixture of Durango cotton with Egyptian also resulted from putting Durango seed into sacks in which Egyptian seed cotton had been carried to the gins. Fields planted with this seed showed a scattering of Egyptian plants among the Durango. The changing of sacks without proper care in cleaning them, it would seem, might be a very common cause of mixture.

The purity of another carefully guarded field of Durango cotton was jeopardized by the carelessness of a neighbor who had left some short-staple seed by the roadside. In preparing the land for the Durango cotton some of the short-staple seed was dragged into the field. The owner knew nothing of this until the scattering short-staple plants were noticed in one corner of the field, and then the origin of the contamination was traced. In this case immediate attention was given to the removal of the short-staple plants, which were easily distinguished from the Durango.

A final instance is that of a farmer who took pains to secure a good stock of Durango seed for planting his field, but he did not secure a complete stand so replanted with Triumph short-staple cotton to fill the vacant places.

As a result of such accidents and oversights a large proportion of the fields are more or less contaminated. But a few of the growers who were able to secure clean seed are following the advice of the Department of Agriculture in order to preserve the purity of their seed. They have planted on land uncontaminated with other cotton and will use proper precaution to prevent mixing with other varieties in handling and ginning the cotton in the fall. They propose to carry through, for planting in 1914, quantities of Durango seed as clean as the stock from which it is being grown this season.

The number of these more careful or more fortunate farmers is not large, but the seed they are raising would plant a large acreage of pure Durango next year if the importance of using clean seed were properly appreciated. But as long as the farmers who have mixed fields can get as high a price for their fiber as those who have pure fields, they are likely to continue the planting of their mixed stocks instead of making a new beginning with pure seed and guarding with more care against contamination in the future.

DISCRIMINATION IN BUYING MORE IMPORTANT THAN HIGH PRICES.

That prices determine the production of a crop is a familiar idea, but the state of the cotton industry shows that high prices alone can not be relied upon to increase the production of superior fiber. The buying of the crop with proper discrimination is just as necessary in establishing and maintaining production as any factor of climate, soil, cultivation, or other agricultural requirement. The higher grades of Egyptian cotton are now worth approximately twice as much as the standard middling grade of short staples, while

Upland long staple brings from 30 to 60 per cent more than middling short staples. Both types can be produced in much larger quantities at such premiums if the premiums are paid to the farmers who produce the superior cotton. Paying high prices without discrimination encourages the wrong class of farmers to plant long-staple cotton, instead of securing the interest of those who might place the industry on a substantial basis.

There is no reason why the farmer who refuses to take the precautions that are necessary to produce good long-staple cotton should get any more for his crop than for short staple. The new early-maturing, long-staple varieties are as productive as most of the short-staple varieties that are now being grown, and in some instances even more productive, as in the case of the Durango cotton in the Imperial Valley. On the basis of the present varieties the greater cost of production of long staples lies entirely in the greater care that must be exercised to produce a more uniform fiber. The farmer who will not take the extra precautions that are necessary with long-staple cotton has no just claim for a premium. Unless the most intelligent and careful farmers can be enlisted, there is little prospect that the culture of long-staple cotton can be established or maintained in any community.

The failure to discriminate in price to the farmer is so general that many buyers do not consider it dishonest, but look upon it merely as one of the ways of increasing the profits of their business. Yet the policy is certainly wrong from the standpoint of agricultural improvement, quite apart from the responsibility of the buyer to pay the farmer a fair price. Indeed, many buyers do not have the skill necessary to determine that one bale contains better fiber than another. In such cases the question of dishonesty need not be raised, but the effect on the farmer is the same. He will not continue the attempt to improve his crop unless he can find recognition in the market price of the cotton. It is no encouragement to him to know that somebody else, whether factor, buyer, or manufacturer, makes larger profits from his improved crop if he is unable to secure a share of these profits.

As long as cotton is bought without regard to quality, it is useless to expect that the farmer will take pains to grow cotton of better quality. The additional care that must be given to the crop to produce superior fiber will not be applied by the intelligent farmer unless he can be assured that the buyer will discriminate and pay more for his cotton than for that raised by his ignorant or careless neighbor. To buy all the long-staple cotton of a district at a flat rate, like short-staple cotton, must be expected to have the same effect with long staples as with short—that of encouraging the planting of the inferior varieties rather than those of higher quality.

The system of buying at a flat rate makes it of interest to the buyer to keep the farmer from knowing how good his cotton is, and this keeps him from trying to make it any better. The buyer, rather than the farmer, draws a temporary advantage from any exceptionally favorable conditions or from the introduction of improved varieties that enable better staple to be produced. In its final result, the present system is opposed to agricultural progress, even to the extent of defeating its own object of securing increased business in handling long-staple cotton.

DEVELOPMENT OF NEW LONG-STAPLE DISTRICTS.

The buyer's function in the general economy of the cotton industry is to take the cotton in small lots from the individual planters and assort it into larger lots of the same kind of fiber for sale to the manufacturer. Unless this work of assembling and classifying the cotton is properly done, so that uniform lots can be sent to the manufacturer, permanent harm may result to the community where the cotton is grown. When the buyer fails to recognize and discriminate in favor of the productive possibilities of a new district the manufacturer also fails, for his judgment is based on the cotton the buyer sends him. If buyers in a certain district send in only mixed or uneven fiber, the manufacturer concludes that the district is not suited to the production of long staples. The manufacturer does not consider that cotton deteriorates because the buyers follow the unfortunate plan of paying the same price for good and bad fiber alike and do not discriminate in favor of farmers who take proper care of their crop. Instead of recognizing that the failure is due to commercial causes, recourse is had to the theory that something is lacking in the climate or the soil, something that prevents the cultivation of long-staple cotton outside of some specially favored region.

This is the history of many attempts that have been made to grow long-staple cotton in new districts. The first plantings with pure seed are successful. The samples are approved by expert buyers and manufacturers, and one or two crops of good staple are raised. But with each season the seed becomes mixed more and more, and about the time that the stage of commercial production is reached the manufacturer finds the staple too uneven for his purposes, decides that the district is not suited to long-staple production, and refuses to make further purchases from that quarter. The buyers or the farmers may be left with unsalable cotton on hand which they can dispose of only with difficulty and at ordinary short-staple prices.

An excellent example of the importance of intelligent buying in the development of a long-staple community is now to be found in South Carolina. A flourishing, long-staple industry is developing in

the district around Hartsville, largely as the result of the public-spirited efforts of Mr. D. R. Coker. This new long-staple industry is based on the Columbia type of long-staple cotton originally selected from a short-staple stock by Dr. H. J. Webber, then of the United States Department of Agriculture. Mr. Coker has not only maintained the Columbia stock and developed special selections from it, but, what is even more important, has assumed the responsibility of buying and finding a market for all of the good Columbia cotton that is raised by his neighbors. Familiarity with the variety has enabled him to buy with discrimination and thus encourage the use of pure seed in a much more effective way than would have been possible if attention had been given to breeding alone without participation in the commercial field. Farmers who mixed their cotton could not sell it except at a lower price than those who had a pure stock, and thus the quality of the long-staple cotton grown about Hartsville has been maintained. Mr. Coker's services to his community as a discriminating buyer should be even more highly appreciated than his efforts at breeding improved strains. There are other districts where the Columbia cotton has fallen into the hands of careless or inexperienced buyers, and where the planting of pure seed was not encouraged by the necessary discrimination in price. The result, as might be expected, is that the New England spinners are buying long-staple cotton from Hartsville while refusing that of other localities where the natural conditions are favorable but where the precautions that are necessary to maintain uniformity have been neglected for lack of proper discrimination in buying. Thus, the presence of a careless or incompetent buyer is a serious danger to the long-staple prospects of a community.

Many unsuccessful attempts have been made to grow Upland long-staple cotton in the Carolinas in the last half century. The last was made a few years ago in connection with a long-staple variety called Florodora, which was planted in many places as a result of extensive advertising of the seed. But the necessary uniformity was lacking in this variety, with the result that both the manufacturer and the farmer were disappointed and returned to the idea that only short staples could be grown to advantage. The lesson that lack of uniformity in the variety was the chief cause of failure was not learned.

The same lack of uniformity is to be expected in any long-staple variety that is brought into a short-staple region and not guarded against admixture with other varieties and degenerate sports. The note of disappointment is already beginning to be heard from manufacturers who have experimented with inferior stocks of Columbia cotton and have thus reached an adverse opinion of the possibilities of a long-staple industry in South Carolina, or in other States where the Columbia cotton may be grown. The history of the Florodora

cotton is likely to be repeated with the Columbia, for mixed stocks are being sold in Texas and elsewhere on an advertising basis, and a large amount of inferior fiber is likely to come into the market.

Of course, there are some parts of the cotton belt, like the drier portions of Texas, where the conditions are not really favorable for the production of long-staple cotton. Only a few varieties and a few localities may be able to produce a staple equal to that of the Mississippi Delta region, but a large part of the cotton belt could produce excellent long staples if proper care were taken. Most of the former attempts at long-staple production failed, in all probability, not because of agricultural difficulties but because the varieties were not kept uniform and because the buyers did not discriminate between the good fiber that was worth a premium and the mixed stocks of long and short cotton that possibly had even less value than short cotton alone. If the mixed fiber had been rejected promptly, no more of it would have been grown and the production of uniform stocks would have continued and increased. Instead of using discrimination in time, the mixing is allowed to go on for two or three years until the stock has deteriorated and the crop has been refused by the manufacturer. Thus, the prospects of establishing a new center of long-staple production are seriously diminished, if not altogether destroyed.

In some respects the best opportunities for developing new long-staple districts are in the irrigated regions of the Southwest. The natural conditions must be admitted to be extremely favorable, with such advantages as rich soil, control of water supply by irrigation, freedom from wet weather in the harvest season, and absence of the boll weevil. Moreover, in these newly settled communities it is easier to secure a general agreement on the planting of a single kind of cotton. In the Salt River Valley of central Arizona, where only Egyptian cotton is grown, the crop has increased from 33 bales in 1911 to 262 bales in 1912, and about 3,000 bales are expected in the present season. In the Imperial Valley of southern California there has been a still more rapid expansion of the Durango cotton from about 3 acres in 1911 to 200 acres in 1912 and to about 5,500 acres in 1913, using all the seed of this variety that could be bought. If the present crop brings a fair price, the Durango variety is likely to be planted next year for the entire crop of the Imperial Valley, or to an extent of 20,000 to 30,000 acres.

The danger that seems likely to interfere with the progress of such communities is that the buyers will continue to follow their usual policy of taking the entire crops at flat prices and thus encourage the farmers to neglect the precaution of keeping the varieties pure. It was not to be expected, perhaps, that the manufacturers who bought the small early crops to encourage the pioneer planters would

give themselves the further trouble of discriminating among the numerous small lots. Nevertheless, it was bad policy to take the mixed, weak, or uneven fiber at the same price that was paid for the best.

The care that must be used in maintaining the quality of future crops is just as necessary as any other part of the work of production, planting, irrigating, cultivating, or picking, but it is a part that has been neglected in the past and is likely to be neglected in the future if the value that it adds to the fiber is ignored by the buyer. In other words, increased production of long-staple cotton is very largely a commercial problem. Further improvements of varieties and methods are to be expected, but the varieties and methods that are now available make it possible to produce almost unlimited quantities of long-staple cotton in the United States. All that seems now to be needed is that the commercial world appreciate its agricultural responsibilities. The supply will correspond to the demand, but the demand must be made effective by proper discrimination in price.

COMMERCIAL CAUSES OF DETERIORATION OF COTTON.

The manufacturing world, in Europe as well as in the United States, seems to be unanimous in the opinion that the cotton crop has deteriorated in recent decades. The same complaint is made regarding all of the principal types of cotton—Upland short staples, long staples, Egyptian, and Sea Island. While direct evidence on the fact of deterioration is not easy to obtain, there is circumstantial support for the idea that deterioration has taken place, for the system of buying has allowed changes that would naturally tend toward a decline in the quality of the crop. The necessary precautions of selection and for avoiding admixture of seed have been relaxed, and even the planting of inferior varieties has been encouraged.

The general disregard of the essential qualities of length, strength, and higher grade on the part of buyers has had the natural effect of leading the farmers to believe that the most desirable character a cotton variety can have is that of giving a high percentage of lint, "a large outturn at the gin." This erroneous idea is now firmly fixed in the popular mind, and is not likely to be eradicated while the present system of buying continues. No matter how inferior in other respects a variety may be, thousands of bushels of seed can be sold by advertising a high percentage of lint.

The fact that some of the varieties with highest lint percentages produce extremely short, inferior fiber does not interfere with the planting of such varieties as long as the farmer can sell three-quarter-inch cotton for as much as inch cotton or even inch-and-an-eighth cotton. The popularity of such varieties is a result of the present

system of buying. In former decades, when the quality of the fiber was considered, nobody would have thought of growing such cotton or of breeding such varieties. In addition to their inferior lint, the high percentage varieties usually have smaller seeds and weaker seedlings, a very undesirable character from the agricultural standpoint. It is easier to secure higher percentages by selecting variations toward small seeds than to increase the amount of lint on the seeds.¹

Manufacturers have assumed or have been led to suppose that the dangers threatening the cotton industry were purely agricultural, such as the exhaustion of the soil, change of climate, or attacks of the boll weevil, and this makes it harder for them to understand that the primary causes of deterioration in the quality of the fiber have been commercial rather than agricultural. This does not mean, of course, that there are not many other agricultural improvements that need to be made, but it does mean that the manufacturer should take greater care to see that the farmer has the necessary inducement to plant superior varieties and to adopt the more careful methods that are necessary to produce better fiber.

DETERIORATION OF THE SEA ISLAND COTTON CROP.

Until recent years some of the planters of Sea Island cotton in South Carolina have been able to sell their crops direct to the European manufacturers. In order to be sure of having the particular strain of fiber that the planter raised, the manufacturer often made contracts for several years in advance and at prices well above the ordinary market quotations. The possibility of securing these advantageous contracts led the more intelligent planters on the Sea Islands to use one of the most highly specialized systems of selection that has ever been applied to cotton or to any other field crop grown from seed. In order to provide the uniformity of fiber so much desired by the manufacturer, the Sea Island planter raised the crop of each year from seed derived from a single individual plant. In order to do this, it was necessary to select a superior individual three or four years in advance and keep its progeny separate while the stock of seed was being increased.

As long as the planters had the prospect of securing a fair return for these precautions, extra care was taken to protect the uniformity of the stocks. But now that the system of buying has been changed and the special contracts are no longer made, the policy of strict selection is being relaxed. A rapid deterioration of the Sea Island crop is said to have taken place, and this is easily understood from the diversity that exists in many of the fields. Some of the planters

¹ Cook, O. F. Danger in judging cotton varieties by lint percentages. U. S. Department of Agriculture, Bureau of Plant Industry, Circular 11, 16 p., 1908.

have abandoned the Sea Island cotton altogether and are now planting Upland short staple varieties. Hybrids between the Sea Island and Upland types are of frequent occurrence, thus adding another factor of diversity and deterioration.

The manufacturers probably believed that they could secure the same cotton at lower prices by letting it go into the open market so that the buyers could secure it at a flat rate, and this they may be able to do, but only for a short time. The decline of the industry has begun, and this course is not likely to be stayed unless there can be a return to greater discrimination in buying. If it be true, as some of the planters believe, that the contracts were withdrawn on the assurance of the buyers that they could furnish the same cotton at lower prices, any such assurance was based on a misunderstanding of the essential factors of production, and the manufacturers have been deceived. The buyers can not continue to furnish the same cotton at lower prices, because the growers will not continue to produce cotton of the same quality.

If the farmers are no longer to look for special prices for special quality of fiber, they will no longer make quality the prime consideration, but must begin to take more account of quantity, as in other branches of the cotton industry. The planters are preferring more prolific stocks and are abandoning the special selections formerly grown on the basis of contracts. The buyer may send the manufacturer cotton from the same plantation, but it is no longer the same cotton. The commercial interests are beginning to recognize this as one of the causes of deterioration of the Sea Island crop, but it is equally important to understand that the attempt to buy the cotton at flat prices places a premium on quantity instead of on quality. Of course, the buyer wants the cotton to have quality when he takes it to the manufacturer, for his profits depend on this, but it is hardly businesslike to expect the planter to provide special quality without being paid for it.

Thus, it may be seen that the plan of buying Sea Island cotton at flat prices without proper discrimination in favor of producers of superior fiber is having the same effect in the Sea Island district as in other branches of the cotton industry. The general tendency is to discourage and cause the neglect of the special precautions that are necessary to produce fiber of the highest quality. The next step in deterioration is a general decline in uniformity and reduction of demand. If these commercial tendencies are not resisted, the ultimate effect must be to discontinue the production and put an end to the superior fiber. The present theory of the commercial world—that larger profits can be made by refusing premiums for superior fiber—if worked out to its logical conclusion, means that all the higher types of cotton will be excluded, so that the cotton production

of the future will be limited to very short staples, three-quarters of an inch or less.

There can be no doubt of the desirability of finding some means of counteracting this tendency toward the planting of inferior varieties. Indeed, some other course must be opened, or further deterioration is inevitable. As long as the farmer accepts the lint percentage or ginning outturn as the sole standard of the value of a variety, the preference for varieties with inferior lint is likely to continue. The only effective way to change the farmer's opinion on this point is to pay him less for the short, inferior fiber and more for the long, strong, and uniform fiber.

LIMITATIONS OF THE PRESENT SYSTEM OF BUYING.

A system of buying that discourages the production of the commodity that it handles is like a transportation line that injures its business by charging more than the traffic will bear. Farmers will not take more pains to grow good cotton merely for the satisfaction of knowing that the buyer can make more money out of it. The farmer must get at least enough advantage to induce him to grow the cotton or the buyer loses his business; and the manufacturer also suffers when the farmer ceases to produce the necessary raw materials. Even if the manufacturers are able to protect themselves against the unskillful buyers, the agricultural damage continues. It is not what the manufacturer pays for the cotton but what the farmer gets for the cotton that determines production.

Long-staple manufacturers have been uncertain of their future supplies and anxious that production should be increased, but they should understand that the remedy is in their own hands. Nothing in the way of permanent progress is to be gained by advising or exhorting farmers to plant better varieties or to maintain their uniformity by selection unless they are able to market superior fiber at higher prices than ordinary or inferior fiber.

Some of the manufacturers have supposed that the production of long-staple cotton could be increased and a more abundant supply maintained by direct action of the Department of Agriculture in urging the planters to grow long-staple cotton. It is desirable, of course, to have the improved varieties brought to the attention of planters, or even urged upon them, but if it appears afterwards that the farmers who have planted the new varieties and taken the pains to carry out the precautions advised by the Department of Agriculture can get no more for their cotton than their careless neighbors, no permanent benefit is secured. Indeed, the reaction that comes with the failure of such efforts often leaves a worse condition than before. There is less inclination to make such efforts in the future or to

adopt other improvements advised by the Department of Agriculture.

The general underlying fact is that most of the farmers are unaccustomed to take the precautions that are necessary to preserve uniform stocks and have no adequate conception of the need of such precautions. Moreover, they are not likely to get such a conception, except through a long educational process, unless the issue is made more practical and direct by greater discrimination in buying. The work of the department is of an educational character, but the information that the department can give the farmer is not likely to be used when it means additional care and effort without any corresponding advantage. When the farmer asks how much more his long-staple crop will bring if he pulls out all of the short-staple plants in the field, he can get no direct assurance. He can be assured that his cotton will be worth more, but not that he can get more, for the chances are that the buyer will be unable to detect the admixture of short cotton. But if the farmer knew that his field was to be inspected and that the presence of short-staple plants would be detected and would result in his receiving a lower price for his crop, he would not hesitate about taking the trouble to pull them out. Farmers are willing enough to adopt easier methods or crops that can be raised more cheaply, but the production of good cotton requires additional attention, something beyond what the farmer has been accustomed to give in raising short staples, and some positive inducement becomes necessary or the extra care will not be taken.

INJUSTICE OF THE PRESENT SYSTEM OF BUYING.

The present system of buying without adequate discrimination means the same average price for lots of cotton that differ greatly in value. Doubtless it is an easier and more convenient system for the buyers to take their cotton at flat prices and classify it afterwards into the different qualities required by their various customers. But, whatever the commercial advantages of this system, it is certainly unwise and unjust in its relation to the farmer. It takes what belongs to the good farmer and gives it to the poor farmer.¹ The farmer who raises cotton above the average in quality is mulcted to make up for the loss on cotton that is below the average. When the nature of the system is considered, it is easy to understand that the general tendency has been toward the growing of inferior cotton rather than to the taking of extra pains from which no advantage could be gained.

No individual buyer, of course, nor any organization of buyers, is to be held responsible for the present system. Buyers, like other

¹ For specific instances of injustice and loss to farmers resulting from the present system of marketing, see Sherman, W. A., Taylor, Fred, and Brand, C. J., already cited.

people, simply have been inclined to take the courses that seemed to promise the easiest returns, without realizing that these courses were so seriously at variance with the interests of both the producer and the manufacturer. But now this divergence of interests has become apparent, and there is no good reason why it should continue. Buyers who wish to do so can learn how to serve their clients better than under the present system. The skillful buyers would do a larger proportion of business as production became more concentrated by community organization. The unskillful buyers, who have been buying the cotton raised by unskillful farmers, would go out of business.

As already stated, it is not a question of paying more for the cotton, but of paying more to the farmers who produce good cotton and less to those who produce poor cotton. This simple expedient would do more than any amount of exhortation to increase the proportion of farmers who would take the care that is necessary to produce good cotton. Buyers who really have the powers of discrimination that are needed in their business would have no serious difficulty in learning how to determine the value of the crop in the field much more reliably than they can determine it by drawing samples from the bales. The risks they now take in trusting to bale samples alone could be avoided almost entirely by learning how to judge the cotton in the field. In order to have a beneficial effect on production, discrimination must be based on real differences in the cotton. Arbitrary discrimination is naturally resented by the farmer as a dishonest effort at buying his cotton for less than its actual market value. When different prices are paid for bales that were raised in the same field, gathered by the same pickers, and ginned at the same gin, the farmer is compelled either to doubt the honesty of the buyers or to question their ability to distinguish the quality of cotton in the bale. Differences of 3 or 4 cents a pound in the valuation of the same lots of cotton are common in long-staple markets.

UNIFORMITY BEST DETERMINED BY FIELD INSPECTION.

Uniformity in the length and strength of the fiber is one of the most important factors in determining the value of long-staple cotton to the spinner. One of the most serious defects of the present system of buying on the basis of samples drawn from the bales is that it is not adequate for the determination of uniformity. Buyers commonly fail to detect an admixture of 5 or 10 per cent of short cotton, and even 15 or 20 per cent often "gets by." The buyers, of course, are not inclined to admit this, but the fact is well known to manufacturers. Differences in the amount of "waste" become apparent, of course, when the manufacturing processes are reached, though they are not to be detected with accuracy by the methods of

sampling upon which the buyer relies. But by field inspection admixtures of 1 or 2 per cent are quite as easily and definitely detected as percentages of 10 or 20 per cent. A buyer or inspector having sufficient familiarity with a variety could establish definite percentage grades of purity of stock for all of the cotton of a neighborhood, and these percentages could be used as a basis for buying. The short-staple plants or inferior individuals stand out very distinctly, so that they can be seen at a glance by those who have sufficient familiarity with a variety, and they can be pulled out or counted as easily as the same number of weeds that a careless farmer might leave in his field.

Buyers are on their guard, of course, against deliberate mixing or "plating" of bales by putting good cotton on the outside and poor cotton in the middle, but when the long and the short cotton grow together in the same field and are picked together the chances of detection are greatly reduced. Dishonest farmers have been known to add a proportion of short-staple seed before planting, in order to increase the yield and sell the crop at regular long-staple prices. This has been done, not alone in out-of-the-way places where there were no regular long-staple buyers, but in recognized long-staple markets. The buyer pulls only two or three samples from the bale, and unless he happens upon short cotton in "pulling the sample" the bales may be passed and paid for as long staple. Hence, the present system of buying affords no protection against the deterioration of varieties of long-staple cotton. The mixture is likely to go on to the point of complete contamination of the stock before the buyer detects the damage.

In failing to make use of the opportunity of judging cotton in the field, the present system of buying becomes wasteful and inefficient. Buying cotton at a flat price without discrimination of quality means that all the different grades and qualities that a region produces are brought together, and then they are sorted out again, though there is much less chance of correct judgment as to quality than before they were brought together. Buying from a knowledge of the cotton in the field would require, no doubt, more work from the buyer than he now applies to his business, but the effort would be worth while and might be expected to find proper remuneration.

FIELD INSPECTION IN THE INTEREST OF MANUFACTURERS.

What the long-staple manufacturers might do, and what they undoubtedly would do if sufficiently alive to their future interests, would be to send men into districts where long-staple cotton is grown, in order to gain direct familiarity with the facts that determine the value of the cotton for manufacturing purposes. The knowledge that might be gained in this way could be used either in

direct buying from the farmer or in placing orders with buyers who would, in turn, find it to their interest to know in advance the possibility of supplying the needs of their more discriminating customers.

The same amount of skill that is now used in classifying cotton in the bale could be applied much more effectively in the field, and with enormous advantage to agriculture in assuring the farmer a return for the special care required to produce superior fiber. The chief obstacle to the adoption of such methods of buying on a basis of field inspection is that neither the manufacturers nor the buyers have, at present, any familiarity with cotton in the field, either with the plants as they grow or with the fiber as it comes from the bolls. A certain amount of time is required to become familiar with the plant and lint characters, as they have to be judged in the field, but anybody who is able to make the fine discriminations necessary in classifying cotton in the bale would have no serious difficulty in learning to distinguish the different kinds of plants in a mixed field or in recognizing differences in the lint while still on the seeds. Indeed, the recognition of such differences is really much easier than the classification of cotton in the bale, because the differences are greater and more obvious, and because it is seldom necessary to depend upon one character alone. Varieties differ, usually, by many characters, and even in the same variety several characters are likely to be changed under a different set of external conditions. If the lint is shortened by adverse conditions, the bolls and leaves are likely to be smaller and the whole aspect of the plants will be different. Sufficient familiarity with the characters and behavior of a variety enables one to tell in advance with considerable confidence the length and strength of the lint before taking it in hand, or even before the bolls have opened.

OTHER CAUSES OF UNEVEN FIBER.

It is true that mixing varieties and diversity among the plants in the field are not the only causes of inequality in the length and strength of cotton fiber. Unless the conditions of growth are favorable, even the best variety may yield only inferior cotton. Adverse conditions during a part of the crop season may render the fiber uneven, notwithstanding the care that may have been taken to keep the stock pure. As a result of differences in the soil, one part of a field may grow good fiber while another part of the same field may yield only inferior fiber. When one side of a field is allowed to grow up in weeds, an adverse effect on the fiber is often apparent. Inequalities of soil or moisture supply are often shown in a striking manner in the growth of the plants.

Any sudden change of conditions of growth, such as checking the plants by drought or forcing them into very rapid development by heat and moisture, is likely to affect the quality of the fiber as well

as the yield. The crop is reduced by the shedding of floral buds and young bolls. Bolls that are farther advanced are not so likely to be shed, but they often fail to reach normal maturity and produce weak, inferior fiber. Thus, long and short fiber or strong and weak fiber are often to be found on the same plant.

Some varieties have a tendency to inequality in the length of lint, the fiber at the base of the seed often being much shorter than that at the top. This difference of length sometimes amounts to half an inch or even more, giving the so-called "butterfly" outline, when the fiber is combed out from the sides of the seed. This factor of inequality may be avoided by choosing varieties that do not have the undesirable butterfly tendency. The new Durango type of long-staple cotton is unusually free from this defect.

There are other factors of inequality in addition to the mixing of varieties or the failure to continue selection. A farmer who has planted pure seed may still have only inferior cotton if his soil is poor or his methods careless, either in raising or picking the crop, or if the fiber is damaged by rain during the harvest season. The condition of the cotton must be taken into account apart from the quality. Good cotton may be in bad condition, but poor cotton can not be made good by careful handling at the end of the season. The farmer who plants mixed seed can not produce uniform fiber, no matter how favorable the conditions or how careful the methods in other respects. Quality is best determined by field inspection, for any form of inequality can be detected in the field much more easily than in the bale.

ECONOMIC PECULIARITIES OF THE COTTON INDUSTRY.

Cotton differs from many other crops in that it can not be used on the farm or by retail consumers in the neighboring town. There is no possibility of the cotton grower dealing directly with an individual consumer of cotton, unless he should return to the manufacture of his own cloth, as in colonial times. The modern industry is organized on the basis of assembling a large quantity of fiber to supply a vast manufacturing establishment. As economy of production depends on this concentration of supplies, we may say that raw cotton has only a wholesale market. The retail market is not reached until the manufactured goods are distributed. Thus, the cotton crop is peculiarly dependent on its commercial environment, because the farmer has no alternative but to sell to the manufacturer or his representative, the cotton buyer. This absence of ordinary retail competition may be considered as a reason for the persistent demand for special legislation to control the marketing of cotton.

The economy and efficiency of the present system of concentration of manufacturing processes depends on the supply of suitable mate-

rials, and a regular supply must be maintained or the whole industrial and commercial structure falls. It may be too much to ask manufacturers to understand the agricultural factors of production, but at least the commercial factors might receive their attention, in view of the important differences between cotton and other crops. Unless the buyer represents the manufacturer to the extent of discriminating in favor of the fiber that the manufacturer wants, the farmer will also fail to discriminate; that is, he will neglect the precautions that are necessary to produce longer and more uniform fiber.

CONCLUSIONS.

The production of cotton of superior quality in the United States is influenced by methods of buying, as well as by the prices paid for the crop. Failure to use proper discrimination in buying encourages careless or dishonest mixing of varieties on the farm or at the gin and leads to deterioration and loss of uniformity, so that the market value of the product is soon destroyed. Long-staple cotton of superior quality could be grown to great advantage in many parts of the American cotton belt if the necessary care were taken to preserve the purity and uniformity of varieties. The natural conditions are favorable for the production of such cotton, and almost unlimited supplies could be grown if precautions against contamination and degeneration were observed.

Manufacturers have complained for many years that supplies of long-staple cotton were inadequate and uncertain, and the boll-weevil invasion has been supposed to jeopardize the very existence of the long-staple industry. But these dangers no longer threaten. New early-maturing varieties of long-staple cotton have been developed; also improved cultural methods that make it possible to produce good crops of long-staple cotton in many parts of the United States despite the presence of the boll weevil. The problem now is to induce the farmers to take the precautions that are necessary to maintain the uniformity of varieties, and the manufacturers who use the long-staple cottons have the key to this problem.

The prices that have ruled for the last few years have been high enough to stimulate the production of long-staple cotton, but the methods of buying have been too indiscriminate to lead the farmer to understand the necessity of maintaining the purity and uniformity of varieties. Little of permanent benefit can come from the development of superior varieties by the Department of Agriculture if the farmer is not led to appreciate the necessity of preserving such varieties after they are placed in his hands. As long as the buyers take inferior mixed fiber and pay as much for it as for the best and most uniform, the farmer can not be expected to observe the precautions that are necessary to maintain the purity and uniformity

of a variety of cotton, nor even to regard very highly the advice of the Department of Agriculture regarding the necessity of such precautions. More general planting of long-staple cottons can not be advised unless marketing conditions are improved.

Greater discrimination in buying would be the most effective way to encourage the production of long-staple cottons, by giving the farmer a more direct interest in maintaining the purity and uniformity of his crop as a means of securing the full market price. The present tendency to buy long-staple cotton at flat prices like short-staple cotton does not encourage greater care and discrimination on the part of the farmer, but encourages the opposite tendencies to carelessness, loss of uniformity of fiber, and degeneration of varieties. Accordingly, there may be urged upon manufacturers and others who are interested in the development of the long-staple cotton industry the importance of improving the methods of buying, so that greater discrimination may be used, instead of paying the same prices for mixed fiber as for fiber raised from pure stocks of seed.

Inspection of the cotton in the field affords a much better basis of judgment regarding the essential quality of uniformity than the present method of pulling samples from the bales. Field inspection should precede warehouse grading, especially with long-staple cottons. Familiarity with a variety of cotton makes it possible to recognize much smaller percentages of admixture or degeneration than can be detected in the bale, thus affording a greater degree of protection to the buyer and manufacturer and at the same time offering a greater inducement to the farmer to maintain the purity and uniformity of his cotton.

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(PROFESSIONAL PAPER.)

POTASH SALTS AND OTHER SALINES IN THE GREAT BASIN REGION.¹

By G. J. YOUNG.

GEOCHEMICAL CONDITIONS.

INTRODUCTION.

The area under consideration in this bulletin embraces practically the entire State of Nevada, the southern part of Oregon, the western part of Utah, and certain sections of eastern and southeastern California. It is confined on the north by the watershed of the Columbia, Snake, and Klamath Rivers, on the south and southeast by the Colorado River, on the west by the Sierra Nevada, on the east by the Wasatch Mountains, and on the southwest by the mountains bordering on the Mojave Desert. It includes the drainage of the Humboldt, Truckee, Carson, Walker, Quinn, Bear, Weber, Jordan, Salt, Sevier, Beaver, Amargosa, Mojave, and Owens Rivers and their tributaries, besides numerous smaller creeks and streams. It is considered as a unit because it has no surface drainage to the sea. Climatologically, it is a part of the arid region of the West.

The total area is estimated at between 208,500 and 210,000 square miles. The term "Great Basin" has received such widespread use and acceptance that we may consider the designation fixed, although it must not be considered as a single basin, but rather as a series of individual basins separated by mountain ranges. These basins are roughly of north-and-south trend. Five major systems may be separated and designated as the Bonneville; the Lahontan; the Amargosa and Death Valley; the Owens, Searles, and Panamint system; and the Oregon Lake system. Of the other lake basins not included in these systems the following may be named: Rhodes Marsh, Teels Marsh, Columbus and Fish Lake Valley, Clayton Valley, Alkali Lake (Paradise Valley, Cal.), Big Smoky Valley, White River, Mono, Saline Valley, Ivanpah, Bristol, Cadiz, and Danby. A complete list of the individual basins making up the Great Basin has been prepared by E. E. Free, and the following table is taken from his paper (The Present and Past Topography of the Undrained Areas of the United States):

Basin.	Description.	Area.	Basin.	Description.	Area.
		<i>Square miles.</i>			<i>Square miles.</i>
Lahontan.....		47,600	Humboldt-Carson..	Part of Lahontan...	27,575
Black Rock.....	Part of Lahontan..	10,500	Fernley.....	do.....	215
Kumiva.....	do.....	445	Allan Springs.....	do.....	235
Granite Spring.....	do.....	890	Sand Springs.....	do.....	200
Jungo.....	do.....	340	Buena Vista.....	Part of Humboldt drainage.	4,000
Hot Springs.....	do.....	270	Buffalo Springs.....	do.....	500
Honey Lake.....	do.....	2,660	Gibson.....	do.....	1,150
Truckee.....	do.....	2,975	Clover (snow water).....	do.....	1,075
Lemmon Valley.....	do.....	90	Walker.....	Part of Lahontan...	3,850
Warm Springs.....	do.....	20			

¹ This bulletin embodies the results of investigations carried on in cooperation with the United States Geological Survey and the Mackay School of Mines, Reno, Nev., with a view to determining the existence or nonexistence of sources of potash salts in the basin region.

Basin.	Description.	Area.	Basin.	Description.	Area.
		<i>Square miles.</i>			<i>Square miles.</i>
Bonneville.....	Once tributary to Columbia River.	57,960	Penoyer.....	Probably tributary to Railroad.	1,000
Steptoe.....	Part of Bonneville..	6,590	Gold Flat.....	Probably landlocked	640
Ruby.....	do.	1,200	Emigrant.....	Probably landlocked (maximum area).	1,000
Butte Valley.....	do.	740	Yuca.....	Probably tributary to Frenchman Flat.	300
Murray.....	do.	720	Frenchman Flat....	Probably landlocked	740
White Valley.....	do.	920	Indian Spring.....	Tributary to Colorado River.	650
Rush Valley.....	do.	700	do.	do.	730
Sevier.....	do.	16,375	Lee Canyon.....	do.	300
Christmas Lake.....	Probably landlocked	2,750	Sheep Range.....	Probably landlocked	300
Silver Lake.....	Part of Christmas Lake Basin.	750	Spring Valley.....	Doubtful.	1,550
Chewaucan.....	Landlocked.	1,500	Gannett.....	Tributary to Colorado River.	150
Summer Lake.....	(Abert Lake).	560	Opal Mountain.....	Probably landlocked	580
Alkali Lake.....	Part of Chewaucan Basin.	400	Mono.....	Landlocked.	770
Warner.....	Landlocked.	2,000	Aurora.....	Part of Mono.	100
Harney.....	Tributary to Columbia River.	2,000	Owens.....	Once tributary to Searles.	2,825
Catlow.....	Probably tributary to Harney.	1,000	Searles.....	Almost always landlocked (maximum area).	4,850
Guano.....	Probably tributary to Catlow.	2,350	Panamint.....	Landlocked (area does not include Searles or Owens).	1,950
Surprise.....	Landlocked (maximum area).	775	Saline Valley.....	Landlocked.	825
Long Valley.....	Probably tributary to Surprise.	610	Eureka Valley.....	Probably landlocked	550
Duck Flat.....	Tributary to Surprise.	3,200	Deep Springs.....	Landlocked.	190
Alvord.....	Probably landlocked	300	Kane.....	Probably landlocked	900
White Horse.....	Tributary to Alvord.	1,300	Willard.....	do.	250
Thousand Creek.....	do.	900	Granite Mountains.	do.	150
Madeline.....	Probably landlocked	900	Owl.....	do.	60
Goose Lake.....	Tributary to Pitt River.	2,660	Death Valley.....	Landlocked (including Mojave and Amargosa).	23,160
Klamath Lakes.....	Tributary to Klamath River.	285	Ralston.....	Part of Amargosa drainage.	1,750
Dixie Valley.....	Landlocked.	400	Stonewall Flat.....	do.	343
Fairview.....	Part of Dixie.	1,250	Sarcobatus Flat.....	do.	755
Edward's Creek.....	do.	130	Pahrump Valley.....	Tributary to Amargosa (maximum area).	1,400
Gabbs Valley.....	Landlocked.	175	Mesquite Valley....	Probably tributary to the Amargosa.	350
Acme.....	Probably tributary to Walker.	65	Soda Lake.....	Part of Mojave drainage.	.....
Luning.....	Probably tributary to Rhodes.	540	Rodriguez Lake.....	do.	.....
Mina.....	do.	90	Harper Lake.....	do.	.....
Rhodes.....	Probably landlocked (maximum area).	320	Coyote Lake.....	do.	.....
Garfield.....	Probably landlocked	115	Cronese Lake.....	do.	.....
Teels.....	Landlocked.	300	Langford Lake.....	do.	.....
Huntoon.....	do.	5,225	Ivanpah.....	Landlocked.	.....
Monte Cristo.....	Doubtful.	550	Bristol Lake.....	Probably tributary to Colorado River.	.....
Columbus.....	Landlocked (including Big Smoky).	3,875	Cadiz Lake.....	Tributary either to Danby Lake or to the Colorado River.	.....
Clayton.....	Landlocked.	550	Danby Lake.....	Probably tributary to Colorado River (maximum area).	4,150
Big Smoky.....	Probably tributary to Columbus.	330	Mesquite Lake.....	Tributary to Colorado River.	.....
Smiths Creek.....	Probably tributary to Big Smoky.	930	Dale Lake.....	do.	.....
Kingston.....	Tributary to Big Smoky.	6,340			
Goldfield.....	Probably landlocked	370			
Diamond Valley.....	do.				
Railroad Valley.....	Landlocked (maximum area).				
Kawich.....	Probably tributary to Railroad.				

The areas given in this table are understood to be approximate. For a description of the basins given the reader is referred to the bulletin already cited.

Recent interest in the development of the potash resources of the United States has directed considerable attention to the possibilities of the Great Basin as a source of this compound. The Bureau of Soils and the United States Geological Survey have maintained investigators in this region for some time. Under the direction of the United States Geological Survey a bore has been sunk in the Carson Sink area to a depth of 985 feet. Many of the smaller basins have also been explored by shallow bores. Through the Bureau of Soils a study of the general conditions in these basins,

and particularly dealing with the geochemical features, has been made. In order to widen out the field and stimulate prospectors and others to direct their attention to this mineral, the Bureau of Soils, the United States Geological Survey, and the Mackay School of Mines established a joint laboratory for the examination of mineral and other naturally occurring substances suspected to contain potash. The results of the United States Geological Survey investigators have been presented from time to time in bulletins.¹

The results of the work of the Bureau of Soils are, in part, presented in a paper by E. E. Free (The Present and Past Topography of the Undrained Areas of the United States).² The purpose of the present paper is to present a review of the information now available on the subject of the occurrence and origin of the salines of the Great Basin region, as well as the chemical data which have been accumulated by the Bureau of Soils and the Cooperative Laboratory. Naturally a review of the geochemical features of a region of this extent will not be complete, but it is believed that such a review will be of value at this time and will indicate quite clearly the lines along which future investigation should be directed.

For an adequate conception of the geochemistry of a region it is necessary to know the principal facts concerning climatology, topography, geology, the surface and underground waters, the evaporation from ground and surface waters, and the distribution and chemical character of the rocks. These subjects will be treated in the order stated.

CLIMATOLOGY.

The Great Basin is spoken of as an arid region, and just what is the significance of this term may be gathered from the tables in the Appendix. These tables have been compiled from Weather Bureau reports on precipitation and temperature. They are grouped in four divisions: Weather stations in Nevada, weather stations in western Utah, weather stations in the part of the basin region included in Oregon, and weather stations in that part of the basin region included in California. The altitude and mean annual rainfall of each station is given. (See Appendix, Table I.) The average (arithmetical mean) annual rainfall of the stations in each group is, for the Oregon group, 13.59 inches; for the Utah group, 12.8 inches; for the Nevada group, 10.34 inches; and for the California group, 4.43 inches. The mean annual precipitation for the entire basin region is 10.31 inches. In arriving at this average the mean for each of the above groups and the area occupied by each group were taken into consideration. The variation of the mean annual rainfall with latitude in the basin region may be approximated from Table II. (See Appendix.) Latitude is less a factor in controlling precipitation than altitude. The basins of the Great Basin in general are characterized by a small rainfall. The higher mountains receive a much greater rainfall. An area of high aridity may be marked out, and this includes the Mojave Desert, the Amargosa Basin, the Owens, Walker, Mono, Pyramid, Carson, and Black Rock Desert regions. In this area the mean annual precipitation is less than 6 inches.

An inspection of the weather reports for the basin region shows that some precipitation takes place in each month of the year. December, January, February, and March are the usual months of maximum precipitation; while June, July, August, and September are the months of minimum precipitation. There is, however, much irregularity in the monthly distribution of the rainfall, and the weather charts do not give an entirely clear conception of the situation. Rainfall may be divided into two classes—the normal winter precipitation and the precipitation which usually occurs in August and September. The latter is in the nature of torrential rains and cloudbursts and is conspicuous in the more arid portions of the region. The normal winter precipitation contributes but little run-off in the arid portions, but the August and September precipitations often result in heavy local run-offs which are important agents in the movement of detrital material from the mountains to the plains. As might be expected, precipitation of this nature is very irregular. Several years may elapse without sufficient rain to even moisten the desert watercourses. Then a period of heavy rains results in turning such watercourses into torrents. Stream flows of this nature are of short duration, but the local work of erosion and transportation may be very great. Were it not for these rains, erosion and deposition in the more arid portions of the basin region would be somewhat inconspicuous and limited principally to the action of wind. The influence of these torrential rains extends over the whole arid region described above. But little study has been made of these

¹ Bul. No. 523, Nitrate Deposits. Bul. No. 530-A, The Search for Potash in the United States; Potash Salts—Summary for 1911. Bul. No. 511, Potash Salts—Their Uses and Occurrence in the United States; Alunite. Bul. No. 530-R, Exploration of Salines in Silver Peak Marsh, Nevada; Press Notice No. 97, Feb. 10, 1913; Prospecting for Potash in Death Valley.

² Circ. No. 61, Bureau of Soils, An Investigation of the Otero Basin, New Mexico, for Potash Salts; Circ. No. 62, Bureau of Soils, Report of a Reconnaissance of the Lyon Nitrate Deposit near Queen, New Mexico.

storms, their distribution, and frequency of occurrence. As might be inferred, the weather reports would not reflect this phase of the precipitation to any marked extent.

The mean annual temperature and the highest and lowest temperatures are given in Table III (See Appendix). It is worthy of note that the temperature range in the basin region is great. Extreme cold often prevails in the northern part and extends well down to the south. Extreme summer heats are characteristic of the southern portions and extend well up to the north. As a consequence of this, rock disintegration would be a not inconspicuous feature of the higher mountains.

TOPOGRAPHY.

The dominant bounding ranges of the basin region are the Sierra Nevadas on the west and the Wasatch on the east. The area between these ranges may be considered as a plain intersected by mountain ranges of a predominantly north and south trend. The plain, which is really a great system of more or less connected intermountain valleys, maintains its elevation of between 4,000 and 5,000 feet altitude over practically the entire northern half of the region. The northern half contains three of the main drainage basins—the Bonneville, the Lahontan, and the Oregon Lake basins. These basins are all close to or within the 4,000-foot contour. The south-central half of the plain slopes gradually to the south, reaching two points of maximum depression—Death Valley on the southwest and Las Vegas Valley on the southeast. If we consider the Salton Lake area as a portion of the Great Basin, we have another point of low depression in the Salton Sink. The principal river within the basin is the Humboldt. This river flows across Nevada and feeds Humboldt Lake, in the Lahontan basin. Of minor importance are the Quinn, Amargosa, Reese, and White Rivers. From the Sierras and the Wasatch Mountains many important streams feed the lakes lying in the Bonneville and Lahontan basins and along the base of the Sierras. Many minor streams flow from the short, steep canyons of the higher mountain ranges of the basin.

The mountains of the basin region are in many instances characterized by steep scarps on either or both sides. Short, steep canyons cut to the summits are the rule. Only in a few instances are gently rising slopes to the higher summits to be found. The topography of the mountains belongs to an intermediate rather than a mature or juvenile type.

The valleys are wide and often of great north and south extent. Fringing the valleys are alluvial fans or cones. They are less noticeable in the north, but become conspicuous in the south, where they reach enormous proportions in the Death Valley region.

An attempt has been made to determine the proportion of mountain and intermountain area. The Sierra Valley, Reno, Wadsworth, and Carson topographical sheets were measured and the areas occupied by mountain, outwash slope, silt, playa, and lake determined by planimeter measurements. A more or less arbitrary division was made between mountain and outwash areas, and between outwash and silt areas. Outwash areas include the alluvial fans or cones fringing the steep slopes of the mountains. Where the contours indicated a 2° to 4° slope, the beginning of the silt area was assumed, while the blue dotted line upon the topographic sheets surrounding the lowest area of an intermountain space was taken as the playa area. Similar measurements were made upon the topographic sheets of the Amargosa River. The results of these measurements, as well as those made in the Owens River Valley, are given in Table IV (Appendix). Figure 1 graphically illustrates the comparison of the areas measured, with the exception of the Owens Valley area. The measurements given may be taken to represent a close approximation to the conditions within the basin region. The mean of the measurements of the Carson and the Amargosa region is: Mountain area, 48.3; outwash slopes, 19.1; silt area, 26.8; playa and water area, 5.5 per cent. The mean may be taken to represent approximately the basin region. The figures may be interpreted to mean that over approximately one-half of the basin region erosion is active, while on the remaining half deposition is taking place, greatest in amount on the outwash slopes and least in the playa and flat portions of the intermountain areas. The material constituting the outwash slopes is, in the main, coarse and angular. It is itself more or less subject to erosion. The fine silt and sand coming from the mountain areas, as well as the eroded material of the outwash slopes, finds its way into the playa areas.

GEOLOGY.

An extensive review of the geology of the basin region would be out of place here. Briefly, all of the geological divisions, with the exception of the pre-Cambrian, Permian, and Cretaceous, are to be found. For our purpose we may consider these geological time divisions in three groups—pre-Tertiary, Tertiary, and post-Tertiary.

Pre-Tertiary rocks embrace a comparatively large area of the basin region. The chief formations are: Cambrian, Silurian, Devonian, Carboniferous, Triassic, and Jurassic. Pre-Cambrian formations have been described by King, Spurr, and Ball, but are relatively unimportant. The eastern and southeastern part of Nevada is characterized by Cambrian, Silurian, Devonian, and Carboniferous rocks. These rocks are quartz-

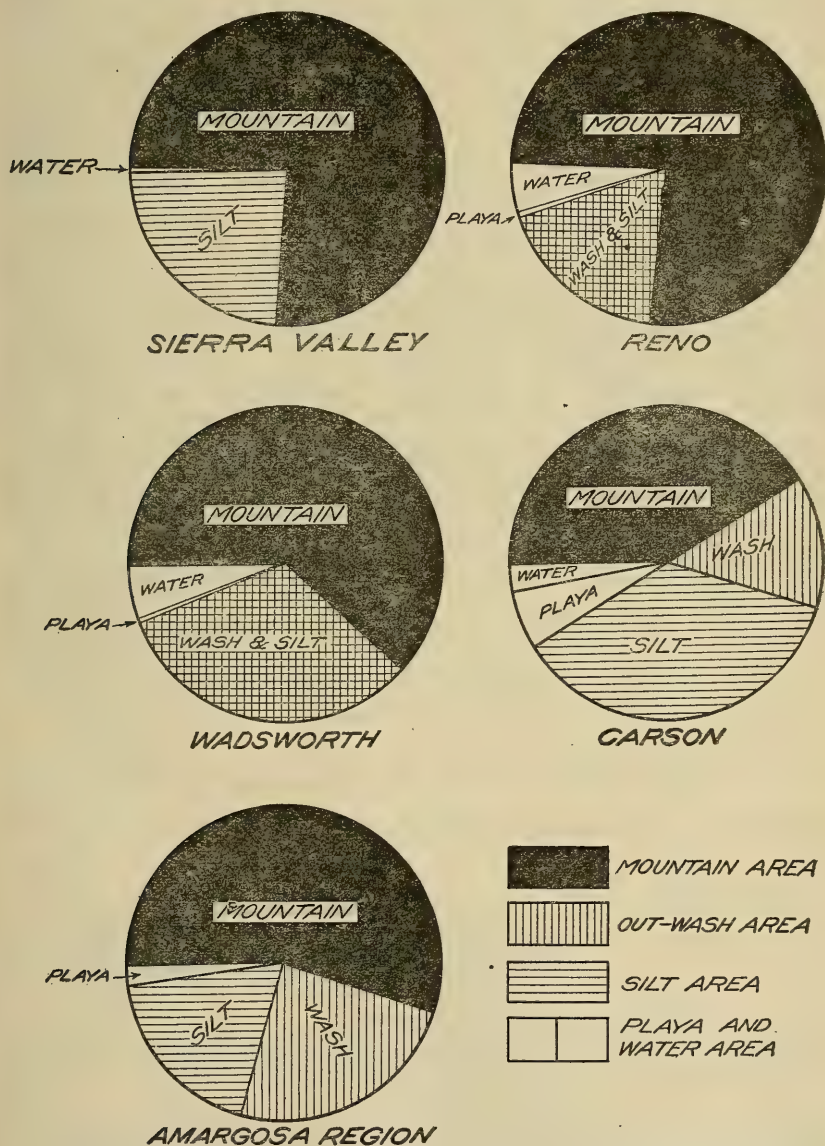


FIG. 1.—Diagrams showing the proportion of mountain and intermountain area in the several districts.

ites, slates, limestones, and sandstones. Triassic and Jurassic formations are relatively less abundant and occur in widely distributed patches in the west-central and southwest portions of the basin region. They consist of limestones, slates, shales, and thin beds of quartzite. In the Triassic are also found beds of gypsum.

Post-Jurassic orogenic movement, accompanied by granitic intrusions, ushered in a period of land elevation and erosion, which continued throughout Cretaceous time.

The conspicuous absence of Cretaceous formations in the basin region, excepting in the Wasatch Mountains and the Iron Spring district of southern Utah,¹ has been noted by many geologists and confirms the conclusion that the basin region was a land mass in Cretaceous time.

The pre-Tertiary was ended and the Tertiary begun by orogenic movement, accompanied by volcanic eruptions. Evidence is not conclusive as to the exact geologic division, but opinion seems to predominate that the beginning of the Eocene marked the beginning of Tertiary volcanic activity, which extended through the Tertiary and into the Quaternary. Following the early volcanic activity of this period, and, no doubt, preceded by crustal movements, was the Tertiary lake period (Miocene)—King's Pahute Lake. During this period the western half of the basin region was occupied by one or more lakes of great extent and irregular outline. Some parts of this lake were, no doubt, of great depth, and the lake period was of long duration, as is shown by the great thickness of sediments exposed in many places (notable examples: Furnace Creek and the Silver Peak quadrangle). The period of lake formation was also a period of vulcanism.

A period of great orogenic movement succeeded the late Tertiary, and during this period the basin ranges were formed and the present topography took its main outlines. The Miocene lakes disappeared. The late-Tertiary is obscure and has yet to be worked out in detail for the region. King was of the opinion that the Miocene lake period was succeeded by another lake period, Pliocene, but Russell has shown that, in so far as the Pliocene sediments (Humboldt formation) mapped by King are concerned, they belong to the Lahontan Lake period. Russell's conclusion is confined to the western portion (Map 5, Geological Atlas, Fortieth Parallel Survey) and does not necessarily include the eastern half of the basin region. Succeeding the late-Tertiary was a period of erosion and continued uplift. The Pleistocene fresh-water lakes were formed. The detailed study of these lakes has shown during this time at least two periods of flooding and an intermediate desiccation. Fluctuations of the Pleistocene lake elevations have been noted also as a conspicuous feature in the history of these lakes. Glaciation in the Sierra Nevada and Wasatch Mountains coincide with the period of the Pleistocene lakes. In recent time desiccation of the Pleistocene lakes has taken place and minor crustal movements have continued.

Our inquiry has for its object the study of saline segregates—their nature, occurrence, extent, genesis, and probable commercial utilization. The basin region has always been considered a favorable place in which to look for saline deposits. The prevalence of volcanic and eruptive rocks indicates a source from which salines might be expected to come. The decomposition of these rocks, the solution of the salts resulting, and the fact that this region possesses no outside drainage have caused geologists to conclude that saline segregates would be found in many of the basins. There is much evidence, which will be discussed in a later part of this paper, to justify this conclusion.

Turrentine has summarized the geological formations and principal localities in which saline segregates have been found. The following table indicates these:

*Geological formations and principal localities in which saline segregates have been found.*²

Geologic period.	Locality.
Recent.....	Kirghiz steppes; Arabia; South America; Dead Sea; Great Salt Lake, and numerous other ancient lakes in western United States.
Tertiary.....	Cardona, Spain; Wieliczka and Bochnia, Galicia; Siebenbürgen; Asia Minor; Armenia; Rimini, Italy; Petit Anse, La.; California, Utah, and Nevada.
Cretaceous.....	Westphalia brines; Algiers.
Jura.....	Rodenberg on the Deister; Bex in Canton of Waadt, Switzerland.
(Keuper.....)	Lorraine; Hall, Tyrol; Hallein and Berchtesgaden (near Salzburg).
Trias.....	Württemberg; in Thuringia, Ernstthal, Stottenheim.
(Muschelkalk.....)	Hanover, Schoeningen near Brunswick, Salzderhelden; Cheshire, England; Kansas and Texas.
(Buntersandstein.....)	
Permian.....	Gera, Artern (Thuringia); Staasfurt, Halle, Sperenberg; Segeberg (Holstein); Kirghiz steppes on the River Ilek; Kansas. ¹
Carboniferous.....	Kanawha and New River, W. Va.; Durham and Bristol, England.
Devonian.....	Winchell, Mich.
Upper Silurian.....	New York; West Virginia; Saginaw, Mich.; Goderich, Canada.

¹ Bul. No. 338, U. S. Geological Survey, Iron Spring District of Southern Utah.

² Turrentine, J. W. The Occurrence of Potassium Salts in the Salines of the United States, Bul. No. 94, Bureau of Soils, U. S. Dept. of Agr., 1913.

³ Haworth, Geol. Survey, Kansas; Ann. Bul., 1897, p. 56. Harris, La. Geol. Survey, Bul. 7, p. 94.

In pre-Tertiary formations salines have been reported from the upper Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, and Cretaceous. These formations, excepting Permian and Cretaceous, are represented to a greater or less extent in the Great Basin. In spite of extensive search on the part of geologists and prospectors, no beds of salines of commercial importance other than gypsum have been discovered. Louderback¹ notes the occurrence of gypsum beds in the Triassic at Mound House and Lovelock. Spurr² notes the occurrence of massive gypsum in lenticular masses in the upper Carboniferous at Cottonwood Springs. Rowe³ notes shales and gypsum beds overlying the upper Carboniferous in the hills north of Cottonwood Springs. A review of the literature leads one to conclude that in the pre-Tertiary formations, excepting the gypsum deposits and minor occurrences of saliniferous layers, the prospects of finding salines of commercial importance are not good.

In the Tertiary formations of the basin region saline segregates have been found. The most important occur in Miocene lake beds. Borates, gypsum, and salt are the important minerals that have been noted. Of these, the borates have been commercially exploited and produce the borax supply of the United States. Up to the present there has been little utilization of the gypsum beds. Concerning the salt beds our information is scanty. G. E. Bailey⁴ describes a bed of rock salt 12 to 16 feet thick in the Saratoga district, San Bernardino County, Cal. He also describes saline beds occurring on the north slope of Avawatz Mountains in the same county. These beds are, without much doubt, in the Tertiary lake series. So far as known no potash salts, at least in commercial quantities, have been reported from the Tertiary. The Tertiary beds are not looked upon by the writer as of any great importance as a source of supply for potash salts. It must be said, however, that comparatively little systematic work has been done upon them. The Tertiary lake beds, as a whole, have contributed by their erosion a large amount of salt and other salines to their tributary basins.

The Quaternary lake beds and the lakes accompanying the Quaternary lake basins hold the most important supplies of salines and are the most promising fields for prospecting. Pre-Tertiary and Tertiary formations have supplied the salts which we find as accumulations in the recent drainage basins and lakes.

Quaternary and recent geologic history has been studied in detail in several of the more important lake basins, and we have in the monographs of Russell and Gilbert ample information of the changes in conditions which have resulted in the formation of saline deposits in these basins. The complete list of the Quaternary lake basins has perhaps not yet been made. From the literature and from personal notes I have compiled the following table:

List of Quaternary lakes.

Name.	Elevation.	Remarks.
Bonneville; ⁵		
Present lakes—	<i>Feet.</i>	
Great Salt Lake.....	4,200	Maximum depth 1,050 feet.
Utah Lake.....	.....	Overflowed.
Sevier Lake.....	.....	
Lahontan; ⁶		
Present lakes.....	4,405 to 4,414	
Honey and Eagle Lakes.....	3,949	326 feet deep.
Pyramid Lake.....	3,880	886 feet deep; 525 feet above 1882 level.
Walker Lake.....	4,083	435 feet deep.
Winnemucca Lake.....	3,875	530 feet deep.
Humboldt Lake.....	3,929	500 feet deep.
Carson Sink.....	3,900	526 feet deep.
South Carson Lake.....	3,916	510 feet deep.
Owens Lake ⁷	3,569	Old beach 190 feet above present level.
Searles ⁸	1,700	Shore line 600 feet above flat.
Panamint ⁹	1,046	1,000 feet above valley floor are wave-cut terraces.
Mono ¹⁰	6,426	Quaternary area 316 square miles; beach 670 feet above lake level.

¹ Bul. No. 223, U. S. Geol. Survey, Gypsum Beds of the United States, p. 118.

² U. S. Geological Surveys West of 100th Meridian, vol. 3, p. 166; and Bul. No. 208, U. S. Geol. Survey, Geology of Nevada south of fortieth parallel survey.

³ Bul. No. 208, U. S. Geol. Survey, Geology of Nevada south of the fortieth parallel, p. 170.

⁴ Bul. No. 24, California State Mining Bureau, p. 126.

⁵ Monograph I, Lake Bonneville. Gilbert.

⁶ 11th Annual Report, Lake Lahontan. Russell.

⁷ Bul. No. 24, Cal. State Mining Bureau.

⁸ 10th Annual Report, Cal. State Mineralogist.

⁹ Bul. No. 200, U. S. Geol. Survey. Campbell.

¹⁰ 8th Annual Report, U. S. Geol. Survey.

List of Quaternary lakes—Continued.

Name.	Elevation.	Remarks.
	<i>Feet.</i>	
Columbus ¹	4,559	Shallow lake 50 to 60 feet deep.
Railroad Valley ²	4,700	Highest shore line 300 feet above flat.
Dixie ²	3,500	Highest beach line 150 feet above floor.
Surprise Valley: ³ Upper, lower, and middle alkali lakes.....	5,190	Highest beach line 550 feet above present level. Two high-water lines.
Lake Alvord ⁴	4,200	Highest beach line 100 feet. Four well-marked and 2 faint lines.
Catlow Valley ⁴	4,600	Highest beach 75 feet. Three well-marked beach lines.
Warner Lake ³	4,600	Highest beach line 225 feet.
Abert Lake: ³ Chewaucan Marsh.....	4,400	Beach line 260 feet above Chewaucan Marsh.
Summer Lake.....	4,300	Beach line 300 feet above Summer Lake.
Jumper Lake.....	4,400	Two shore lines 30 and 60 feet above present lake.
Long Valley.....	5,945	Shore line 250 feet above present level.
Silver Lake.....	4,340	Beach line 100 feet above present level.
Christmas Lake.....		
Madeline Plains.....	5,400	Overflowed.

Ruby and Franklin Lakes, Nev.; Danby and Bristol Lakes, Cal.; and Diamond Valley, Nev., doubtful. Tahoe Lake reported by Diller to show old shore lines above the present lake level.

¹ H. S. Gale (?)

² E. E. Free.

³ 4th Annual Report, U. S. Geol. Survey. Russell.

⁴ Water Supply Paper 231.

Ratios of basin area to lake area, and of Quaternary lake area to present lake area.

Lake.	Basin area.	Quater- nary lake area.	Ratio of basin area to Quater- nary lake area.	Present lake area.	Ratio of Quater- nary area to pres- ent area.
Bonneville	52,000	19,750	2.63	2,498	7.9
Lahontan	47,600	8,422	5.65	734.6	11.4
Total	99,600	28,172	3.53	3,232.6	8.71

Total present area of all the lakes in the Great Basin, 4,196 square miles.

Total area of all the Quaternary lakes, estimated, 36,547 square miles.

Ratio of total area of Great Basin to total Quaternary lake area, $\frac{210000}{36547} = 5.74$; to total present lake area, $\frac{210000}{4196} = 50$.

The present lakes, occupying in many instances the lowest depressions in the Quaternary lake basins, are given in the next section. The chemical data concerning both the Quaternary and the recent lakes and their basins will be given in another section of this report.

SURFACE WATERS.

Complete data are not available for the determination of the total run-off in the basin region. From the Water Supply Papers of the United States Geological Survey it is possible to secure data for the principal streams, but many small streams of local importance are to be found in the mountains of the Great Basin, and for these we have practically no data. These streams contribute to the underground-water supply, but seldom do their waters reach the surface of the playas except in periods of unusual rainfall. The ponds and shallow lakes resulting are quickly evaporated.

The principal streams are: In western Utah, the Weber, Bear, Logan, Spanish Fork, Sevier, and Provo; in Nevada, the Humboldt, Truckee, Carson, Walker, Reese, Quinn, and Amargosa; in California, Susan River, Owens River and tributaries, Leevining Creek, Mill Creek, and Mojave River; in Oregon, small creeks and streams which contribute to the lakes in southern Oregon. Such data as are available for the above streams are given in Tables V, VI, VII (Appendix).

Basin river streams may be divided into three types:

(1) Streams characteristic of the higher mountains. These are short streams which take care of the winter precipitation and carry their waters to the outwash slopes to be distributed by the porous detrital fans.

(2) Streams, such as the Amargosa, Reese, and Quinn Rivers, which reach main basins but do not carry sufficient water to make a continuous flow, or which reach basins of such magnitude that they can not form permanent lakes.

(3) Streams which supply permanent lakes. The drainage of the Sierra Nevada and Wasatch Mountains supplies practically all of these lakes. Owens, Mono, Carson, Walker, Pyramid, Honey, and the lakes of southern Oregon are typical examples of such lakes in the west; while Great Salt Lake, Utah Lake, and Sevier Lake are in the east and are supplied by the drainage of the Wasatch Mountains.

A list of these lakes, together with elevations and drainage area of basins, is given in Table VIII (Appendix).

The proportion of the annual precipitation which appears as run-off varies in different basins. The length of the stream and the character of the watershed, as well as local climatic conditions, determine this factor. The following table summarizes the run-off factor for the Carson, Walker, Truckee, and Humboldt Rivers.

Proportion of rainfall distributed in the run-off.

River basin.	Average rainfall, mean annual.	Run-off.	Run-off in percentage of average rainfall.
	<i>Inches.</i>	<i>Inches.</i>	
Carson.....	11.5	6.25	54.3
East Fork Walker.....	11.5	2.63	22.8
Truckee.....	23.82	9.13	38.9
Humboldt.....	8.12	0.25	3.07
Whole basin region.....	10.31	1 0.71 2 1.19	1 6.80 2 11.50

¹ By calculation based upon the total mean annual stream flow, plus an additional amount estimated at one-half the known amount for the flow of the streams upon which no data are available.

² By calculation based on an assumed rate of evaporation of the water from the lakes into which the rivers flow.

In addition, an attempt has been made to calculate the probable total run-off for the whole basin region. The first calculation is based upon the total mean annual stream flow plus an arbitrary amount for the flow of the streams upon which no data are available. The additional amount has been estimated as one-half of the known amount. This gives a run-off equivalent to 0.71 inch, or 6.8 per cent of the total precipitation. The second calculation is based on an assumed rate of evaporation of the water from the lakes. The total area of lake surface is 4,196 square miles. Assuming an annual evaporation of 60 inches gives an annual run-off of 1.19 inches, or 11.5 per cent of the average annual precipitation. The latter figure is undoubtedly high, as in the southern half of the Great Basin the run-off is practically zero. For instance, the Amargosa River is a typical desert stream and flows only at rare intervals and during periods of excessive precipitation. At other times water occasionally rises in springs from the dry bed, flows a short distance, and then sinks. The run-off for this whole southern area must be less than 1 per cent.

As more than 50 per cent of the area of the Great Basin is flat, or characterized by slopes of low angles (0 to 5°), it may be assumed that for areas of this nature, receiving 10 inches or less mean annual rainfall, the run-off is practically zero. For the basin ranges themselves the run-off can not be in excess of 50 per cent, and it is probably much less. Much of this run-off is absorbed by the outwash slopes. We may take the Humboldt River as an example to illustrate this point. This stream rises in the Ruby Range, upon which there is considerable precipitation. At Oreana the mean annual flow gives a run-off of 0.25 inch (drainage area, 13,800 square miles), or 3.07 per cent of a mean annual rainfall of 8.12 inches. This means that most of the rainfall in the mountains along the course of the Humboldt is absorbed before it can reach the main river.

The basin region may be divided into mountain area, outwash area, and combined silt and playa areas. These approximate 50, 20, and 30 per cent, respectively, of the total area. An inspection of the precipitation tables given on a preceding page shows

that the lowest part of a basin often receives less than 5 inches of annual rainfall and the surrounding mountains a much larger amount. The disposal of the rainfall is illustrated in the following summary:

Distribution of rainfall.

Region.	Percent- age of whole area.	Mean annual precipita- tion.	Percentage.		
			Evapora- tion.	Seepage.	Run-off.
		<i>Inches.</i>			
Mountain area.....	50	13	50	10	40
Outwash area.....	20	10	50	40	10
Silt and playa area.....	30	5	100	.....	.....

Of the run-off from the mountain area given in the above table probably more than one-half is lost by seepage in the outwash area. This would leave only 20 per cent of the mountain rainfall as run-off, and of the 10 per cent run-off of the outwash area we might well say that all is lost by seepage. Twenty per cent of 13 inches is 2.6 inches. This comes from one-half of the entire area and would be equivalent to 1.3 inches over the whole area. A large part of the seepage water is brought to the surface by capillarity and lost by evaporation. It is admitted that the proportions estimated for evaporation and seepage in the above table are more or less arbitrary. Still, we may qualify some of these figures by comparison. The run-off factors for streams in the Sierra Nevada Mountains vary considerably. The average for the Kings, Merced, Tuolumne, Tule, Kern, Carson, Walker, and Truckee is 42.7 per cent. This would justify the 50 per cent run-off figure estimated. For the outwash slopes a percolation figure of 80 per cent is not unreasonable and for the silt areas 100 per cent.

From three lines of inquiry are obtained 0.71, 1.19, and 1.30 inches as the run-off for the basin region. The mean of these is 1.06 inches, or 10.3 per cent of the mean annual precipitation of the Great Basin.

It should be noted, however, that the southern portion of the basin region is characterized by a scanty and irregular run-off, only a fraction of that indicated above, while the run-off for the area contiguous to the Sierra Nevada and Wasatch Mountains is, no doubt, much higher than the above.

EVAPORATION.

Practically all of the rainfall of the basin region is lost by evaporation. During periods of excessive precipitation there is undoubtedly an increase and during periods of aridity a decrease in the amount of ground water. Evaporation from the surface of lakes, from the surface of the ground, and the transpiration of plants are the three ways by which the water is taken back into the atmosphere. How important each of these factors is in the basin region is the subject of our inquiry.

Many experiments to determine the amount of evaporation from surface waters have been made and variable results have been obtained. Some of these results, such as more particularly apply to this region, are given in the following table:

Evaporation from water surfaces.

Locality.	Conditions.	Annual evapora- tion.
		<i>Inches.</i>
Owens Valley region, Cal. ¹	Evaporation from pan in water, 1909 and 1910.....	69.05
Owens Valley region, Cal., Owens Lake.	Deep tank in soil, 1910.....	65.44
Bishop.....	Pan in irrigation ditch.....	69.01
Fallon, Nev. ²	4-inch pan floating in canal.....	80.00
Lake Tahoe, Cal.....	4-inch pan 2 inches above water.....	60.00
Salton Sea, Cal.....	4-inch pan 7,500 feet from sea.....	53.65
Pyramid Lake, Nev. ³	Estimated from mean flow of Truckee.....	42.21
Great Salt Lake ⁴		106.45
		60.00
		90.00

¹ Bul. No. 294, Water-Supply Papers.

² American Civil Engineering Pocket Book.

³ Bul. No. 52, Nevada Exp. Sta.

⁴ U. S. Geol. Survey Report No. 11.

Evaporation from water surfaces varies with the seasons. It is greatest in the summer and fall months. In the Owens River region 73 per cent of the annual evaporation takes place in the six summer and fall months, and the remaining 27 per cent in the winter and spring months. We have not sufficient data to strike an average for the whole basin region, but it is believed that an annual evaporation of 60 inches would fairly represent that which takes place from the surface of the lakes in the basin region.

From an intensive study made of conditions in the Owens River basin ¹ the following figures for the evaporation of water from ground surfaces are taken. The annual ground-surface evaporation depends largely upon the depth of ground water. Where the ground water exceeds 10 feet in depth practically no water is lost from the surface. Where ground water and ground surface coincide the maximum of 42.3 inches per year is found; with ground water at a depth of 1.34 feet from the surface 39.95 inches is found; and with ground water 4.98 feet below the surface 7.9 inches is found. Of the annual evaporation the summer and fall months account for 79 per cent of the total.

Observations in the same locality established the fact that even in a wet season percolating water does not penetrate to depths exceeding $2\frac{1}{2}$ feet unless more than 1 inch falls within a short period on moist soil. Even then it does not appear to reach depths greater than 4 feet. We would conclude from these observations that on detrital fills, on levels, or on low slopes, much of the rainfall is retained close to the surface and seldom penetrates to depths reaching 10 feet. It can not, therefore, form any permanent addition to the ground water, but must be lost by capillarity and evaporation. On steeper slopes the water penetrates slowly downward and in the lower portions of such slopes may be expected to accumulate sufficiently to reach the 10-foot level, and thus a part escapes loss by joining the permanent ground water. Streams debouching upon outwash slopes raise a ridge in the ground-water level and contribute a part of their seepage loss to permanent ground water. We would also conclude that ground water 10 feet or more from the surface would be permanent, and that ground water reaching the 10-foot level or less would be reduced in amount by evaporation. It should be noted that this limit of 10 feet can not be applied to all conditions, for in very fine silts capillarity would no doubt extend to a greater depth than 10 feet. It does, however, establish a limit under what we might term average conditions within which capillarity becomes effective. We would expect in all regions of the basin where ground water reached within the 10-foot level that a slow upward movement of moisture would follow. In this manner soluble salts would be brought to the surface or close to it and would appear as incrustations or be deposited within the surface soil. We should be safe in concluding that where surface incrustations are found in quantity ground-water levels are apt to be within the 10-foot limit. This is, of course, not an entirely accurate criterion, for surface waters may penetrate to depths of several feet and be returned by capillarity, carrying with them dissolved salts to the surface, where they would crystallize and form efflorescences.

Still another fact should not escape our attention. If we assume a soil void space of 25 per cent of volume, a depth of 30 inches of water would be necessary in order to saturate the soil to a depth of 10 feet. In a loose coarse soil but a small fraction of these 30 inches would be required for water to penetrate and reach to a depth of 10 feet. In a mixed soil with much fine silt and clay probably a large proportion of this would be retained, if it penetrated at all, in the upper 10 feet. The low average rainfall of the desert region, together with the observed facts concerning the penetrations of soil by rainfall in the Owens region and the fact noted above, would lead us to conclude that were it not for the concentration of part of the rainfall into stream flows the ground water of the basin region would be a negligible quantity and would be present only in those places where subterranean supplies could act as feeders or in places occupying the lowest depressions of the surface. While these conclusions may be accurate for present climatic conditions it must be kept in mind that the basin region has been subjected to many climatic changes. Humid periods have alternated with arid. We may be not greatly in error when we say that the underground water supply of the basin region is perhaps consequent upon the greater rainfall of the Quaternary period and not upon present climatic conditions.

The surface of the Great Basin is covered with sparse vegetation. One is apt to get the idea from reading maps that vegetation is extremely scarce in the basin region, but we find some kind of vegetation over the whole area, with the exception of the playas and areas occupied by alkali incrustations. Many of the mountain ranges of the basin are thickly covered with grass, and sagebrush dominates over vast areas of plain and mountain slope. We have no accurate determinations of the transpiration loss of desert plants. Such work as has been done on this question has concerned

¹ Water-Supply Paper No. 294.

itself usually with farm crops. On the whole this question has no very important bearing upon our problem and may consequently be dropped.

In the section on surface waters it is shown that approximately 10 per cent of the mean annual rainfall occurs as run-off in the basin region. The evaporation from lakes, rivers, and transient ponds would be measured by this run-off. The remaining 90 per cent of the mean annual precipitation would be a measure of the evaporation from the surface of the ground, by transpiration of plants, and additions by seepage to permanent ground water. It is believed that the addition to permanent ground water is relatively small.

GROUND WATER.

A comprehensive study of ground-water conditions in the Great Basin has yet to be made. Some important information pertinent to our subject is available. I have summarized the data under the following heads: Ground water in valleys and sinks; in outwash slopes; deep supplies of water; artesian water; springs; and fissure and rock water.

VALLEYS AND SINKS.

Ground water is encountered in the Lovelock Valley at depths of 15 to 25 feet.¹ In this valley, after a considerable period of irrigation, ground water has been found at depths of 3 to 6 feet. The figures given in the first statement would represent original conditions, before irrigation took place. This valley is a silt-filled valley on the lower stretches of the Humboldt River.

In the Truckee meadows ground water is found at 10 to 12 feet from the surface in the vicinity of Reno, and on the eastern edge of the Truckee Meadows it stands practically at the surface. In south-central Oregon and the Harney Basin much detailed information is available. In Christmas and Silver Lake Valleys 46 wells and bores have been reported.² Most of these wells are located in the valley and lake silts. The depth to ground water varies from 5 to 49 feet. The average depth of water in all the wells reported is 18 feet. In the Harney Basin 46 wells have been reported.³ The average depth of water in these wells is 21 feet.

In the Owens River Valley, Cal., a survey of underground waters was made by the United States Geological Survey,⁴ and these were found to stand at 2 to 3 feet below the surface over considerable areas. Over the comparatively level valley floor west of Owens River and included within the 8-foot contour above the river (67 square miles of surface) "the average depth to ground water between 4 and 8 feet extended over 40 per cent of this area, and between 3 and 4 feet over 28 per cent. It extends 8 feet in depth over 14 per cent of the area and is 3 feet or less over 18 per cent."

In the Silver Peak Marsh borings showed ground water at 2 to 12 feet depth and, in the case of many of the bores, water was encountered at 4 feet.⁵ In the sink in Death Valley water is found a few inches below the salt crust and potholes in the rough salt areas indicate that ground water stands within 1 or 2 feet of the surface over a considerable area. On Searles Marsh Dolbear⁶ reports the brine (over the salt area) to be within one-half inch of the surface.

At Millers, Nev., wells have been sunk in the desert sands of Big Smoky Valley and water sufficient to supply 160 stamps has been tapped at a depth of 65 feet. The ground water in Big Smoky Valley undoubtedly comes much closer to the surface in the playa southwest of Millers.

Mina is situated in the valley which forms the south extension of the basin occupied by Walker Lake. It is a typical desert valley. Two wells struck water at 112 and 118 feet from the surface.

Other examples could be cited, but these are sufficient to show that in the playa areas and the low areas generally we may expect to find ground water at no considerable depth from the surface. The area within which the ground water would collect would depend upon the extent of the tributary basin and the rainfall within the basin.

OUTWASH SLOPES.

The ground-water conditions in the outwash slopes may best be illustrated by the following quotation⁷ describing the conditions in the Owens River Valley:

"The ground-water surface as it approaches the valley floor from the west has an average slope of 90 feet to the mile. The corresponding slope of the ground surface

¹ Bul. No. 52, Agr. Expt. Sta., University of Nevada.

² Water-Supply Paper No. 220, U. S. Geol. Survey.

³ Water-Supply Paper No. 231, U. S. Geol. Survey.

⁴ Water-Supply Paper No. 294, U. S. Geol. Survey.

⁵ Bul. No. 530R, U. S. Geol. Survey, pp. 7-11.

⁶ Engineering and Mining Journal, Feb. 1, 1913, p. 260.

⁷ Water-Supply Paper No. 294, p. 76.

is steeper, varying from 150 to 110 feet to the mile. At the upper edge of the grass-land the two surfaces are about 8 feet apart and a short distance beneath they intersect in the spring belt. From this belt to Owens River the distance to ground water varies from 4 to 12 feet beneath the gently sloping or level valley floor. This sudden break in the slope of the ground-water surface at the spring belt is caused by the change from coarse to fine material in the region of the late lake. The fine material acts somewhat like a dam, raising a portion of the ground water to the surface in springs and retarding the lateral movement of the remainder."

The above quotation indicates a condition which must be common in basins characterized by surrounding alluvial cones. The ground-water level assumes a sloping surface, and, as we ascend the cone from the valley, we find this ground-water surface at greater and greater depths. We would expect that in every case at the toe of the alluvial fan the ground-water level would be closest to the surface and deepest in the vicinity of the bordering mountains. The amount of seepage water that would collect from the contiguous watersheds, together with the rainfall, would determine whether the upper surface of this ground water would be close to or at considerable depth from the surface.

DEEP SUPPLIES OF WATER AND ARTESIAN WATER.

The bore hole put down by the United States Geological Survey in the Carson Sink region encountered surface waters at a depth of 4 feet, and at depths greater than 150 feet a number of artesian flows were encountered. The well which was put down some 985 feet flowed water.

The Railroad Valley Saline Co. sunk a 1,200-foot bore in Railroad Valley. They discovered many flows of artesian water from the 128-foot depth downward. Twenty-nine separate flows are noted in the log of their well within the first thousand feet. At greater depth the formations were dry.

Artesian areas are known in Smith Valley, Nev.; the Truckee Meadows south of Reno; the Carson Valley, Nev.; the Las Vegas Valley, Nev.; the Salt Lake Valley, Utah; and in southern Oregon. These instances lead us to conclude that water-bearing strata exist in many of the inclosed basins and at depth, and in many cases that they are capable of supplying artesian water.

SPRINGS.

Many springs exist in the Great Basin region. A complete list of these springs can not be given at this time. Russell, in his study of the Quaternary lakes of western Nevada, mapped the springs occurring in this area. He shows 93 springs in an area of approximately 38,000 square miles. Of these 23 are hot springs. Outside of this area hot springs are encountered in many places. South of Beowawe some 6 miles are a number of hot springs and geysers. Just west of Elko is a large hot spring. Sixty miles north of Elko is an area in which several hot springs of considerable size occur. At Rhyolite, Nev., several small hot springs are to be found. Some 12 miles northwest of Goldfield is a hot spring of moderate size. In Railroad Valley a large hot spring has been found. The prevalence of hot springs in the basin region may be assumed to indicate the presence of deep-seated waters. Hydrothermal activity has long been noted as an important feature of the basin region. In earlier geological periods undoubtedly much greater activity existed than at the present.

FISSURE AND ROCK WATER.

That much water may be expected in fissure and brecciated zones in the mountain ranges is shown by the volumes of water encountered in mining operations. Virginia City is perhaps the most conspicuous example. In these mines hot springs have been encountered at depths below 1,000 feet, and a water flow approximating 8,000 gallons per minute represents the drainage from the rock masses of Mount Davidson within the area tapped by the mines. In the Eureka district in central Nevada water was encountered in the mines. In many of the other mining districts water in greater or less amounts has been encountered with depth.

EXTENT, DISTRIBUTION, AND CHARACTER OF THE ROCKS OF THE BASIN REGION.

Volcanic rocks distinguish the basin region from other regions of the West. In order to get some idea of the distribution of the different rocks in the basin region, measurements were made upon the geological map of the Truckee folio, upon maps Nos. 4 and 5 of the Fortieth Parallel Survey atlas, and upon Ball's map of southwestern

Nevada and eastern California. The areas represented by each formation were measured by a planimeter and the proportion of the whole area determined. The results of these measurements are given in Table IX. (See Appendix.) In the following summary the various volcanic and Plutonic rocks have been grouped: Rhyolites and granites; andesite basalts, diabases, and diorites; metamorphics, limestones, and sedimentary and water areas.

Areal distribution of rocks in the Great Basin region.

Rock.	Truckee quad-range.	Fortieth Parallel Survey Atlas.		Ball's map of south-west Nevada and eastern California.
		No. 5.	Nos. 4 and 5.	
Rhyolite and granite.....	22.0	18.8	¹ 22.5	21.5
Basalt, diabase, and diorite.....	45.1	14.2	25.5	11.5
Metamorphic.....	6.15			
Limestone.....				12.1
Sedimentary and water.....	26.8	67.0	53	54.9

¹ Assuming area of rhyolite and trachyte is one-half rhyolite and one-half andesite.

The total areas occupied by igneous rocks are as follows: For the Truckee sheet, 67 per cent; for map No. 5 of the Fortieth Parallel Survey, 33 per cent; for maps Nos. 4 and 5 together, 48 per cent; for Ball's map, 33 per cent. The Truckee sheet may be considered as descriptive of an area in which igneous rocks dominate. This area would not be a fair representation of the whole basin region. The results obtained from the other three measurements indicate a range of 33 to 48 per cent. Which of these two measurements could be taken as representative of the basin region as a whole is a matter of doubt. Probably 40 per cent would be a fair figure to indicate areal distribution of igneous rocks in the basin region. This would leave 60 per cent for sedimentary and alluvial formations. On this basis some 84,000 square miles of the basin region is occupied by igneous rocks. We may assume that acid rocks take somewhat less than one-half of this area and basic rocks somewhat more than one-half.

The chemical composition of the rocks of the basin region has been determined by averaging the reported analyses of the various rocks. Table X (Appendix) gives the results of this study.

SOURCES OF SALINES.

The salines of the basin region consist of mixtures of chlorides, sulphates, carbonates, bicarbonates, nitrates, and borates of sodium, potassium, calcium, and magnesium. Lithium, alumina, ferric oxide, silica, bromine, iodine, phosphoric and arsenious acids have been detected in small amounts in the brines and waters of the basin. Alumina, ferric oxide, and silica are almost invariably found in small amount in river and lake waters and associated with saline crusts. Spectroscopic examination shows lithium in small quantity to be widely associated with saline material.

Salines result from the disintegration and decomposition of igneous and sedimentary rocks, from the decomposition of alluvial and detrital fills, and from the waters of springs of deep-seated origin. During Quaternary times the basin region was the scene of numerous volcanic eruptions. How important these were as contributors to the salines can not now be told, but they must have been not unimportant sources of saline material.

IGNEOUS ROCKS.

In a previous section it has been shown that approximately 40 per cent of the basin area is covered by igneous rocks, and that somewhat less than one-half of this area is represented by rocks of an acid type, while somewhat more than one-half is represented by rocks of a basic type. The composition of the more important types of igneous rocks is given in Table X (Appendix). From the figures in this table the following table has been calculated:

Chemical composition of the more important basic and acidic rocks.

Constituents.	Type, acid.	Type, basic.	Constituents.	Type, acid.	Type, basic.
Base:	<i>Per cent.</i>	<i>Per cent.</i>	Acid:	<i>Per cent.</i>	<i>Per cent.</i>
MgO.....	1.05	4.52	S.....	0.370	0.066
CaO.....	2.15	6.33	Cl.....	.015	.068
Na ₂ O.....	3.35	3.29	CO ₂	.160	.326
K ₂ O.....	4.10	2.09	SO ₃	.035	.....
			P ₂ O ₅	.145	.240
Total.....	10.65	16.23	Total.....	.735	.700

The table gives the average percentage composition of acid and basic divisions of the igneous rocks. Only those constituents have been included which might be expected to contribute to the bases and acids of salines.

Hydration and carbonation are the two important processes by which igneous rocks are decomposed. The rate at which decomposition proceeds is dependent upon the rate of disintegration, as well as upon the intensity of hydration and carbonation. Hydration and carbonation are dependent for their intensity upon climatic conditions. Disintegration depends upon extremes of temperature, the physical nature of the rock, the activity of erosion, and the rate of decomposition of the rock constituents. Disintegration and decomposition proceed simultaneously. Under arid climatic conditions, such as pertain in the basin region, disintegration is dominant and decomposition is measurably less than under humid climatic conditions. This fact has been pointed out by a number of investigators—Van Hise, Merrill, Hilgard, Clarke. Further confirmation of this fact may be easily obtained by petrographic examination of the alluvial material taken from the aprons bordering the basin ranges. Comparatively fresh particles of feldspar may be found even in the finer silts of the central parts of the basin.

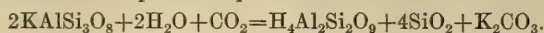
The extent to which the igneous rocks of the basin region have been decomposed, and the constituents and proportion of each which might be expected to form accessions to the salines, have not been made the subject of special study. In a general way it might be said that the amount of rock decomposition in this region is nominal. Pre-Tertiary igneous rocks (in the main granites and diorites), where exposed, are noticeably decomposed. The older Tertiary volcanics (andesites) are also decomposed to a considerable extent. This is particularly noticeable in the areas in which hydrothermal activity was once dominant. In such areas decomposition extends locally to comparatively great depths and the rock alteration is in many cases profound. In the basin region there are some 350 mining districts. Each of these may be considered to have been in the past the locus of more or less hydrothermal action. The aggregate altered rock area of these districts is not known, but it must constitute an extremely small part of the total basin area and be therefore relatively unimportant as a source of saline material. Late Tertiary rhyolites and Quaternary igneous rocks are often only superficially decomposed, except in those regions where hot springs have continued their activities to comparatively recent times.

Humid conditions exist only on the highest mountain ranges and consequently the areas exposed to weathering under the most favorable conditions for decomposition must constitute a relatively small part of the total. Over a large part of the area exposed to weathering influences the conditions in the Great Basin are such as to produce decomposition at a comparatively slow rate at the present time. That this was not always the case has been shown by the investigations of Gilbert and Russell. It is to be particularly noted that in Quaternary times climatic changes were numerous and humid conditions alternated with arid conditions. During the period of Quaternary lake development the rock decomposition must have proceeded at a very much more rapid rate than under present conditions. Consequently a greater amount of saline material must have been contributed and have been deposited in the basins.

The minerals constituting igneous rocks are attacked at different rates. Clarke states: "The pyroxenes and amphiboles yield most readily to waters; then follow the plagioclase feldspars, then orthoclase and the micas, with muscovite the most resistant of all. Even quartz is not quite insoluble, and the corrosion of quartz pebbles in conglomerates has been noted by several observers. Among the common accessories, apatite and pyrite are most easily decomposed, magnetite is less attacked, and such minerals as zircon, corundum, chromite, ilmenite, etc., tend to accumulate with little alteration in the sandy rock residues."

This conclusion no doubt applies to conditions more nearly approaching humid than arid. We should expect under arid conditions, that the more insoluble minerals

would be relatively less affected than the more soluble. Orthoclase and muscovite are the two chief potash-bearing minerals. They are also the most resistant to weathering. This, together with the fact that the acid rocks which contain these minerals are relatively less abundant than the basic rocks which contain the plagioclase feldspars, would lead one to conclude that potash would be found in the salines in much smaller quantities than soda. Van Hise, in discussing the decomposition of orthoclase, shows that this mineral may be altered into kaolin with the liberation of all of the potash in the form of potassium carbonate, or into muscovite with the liberation of only two-thirds of the total potash as potassium carbonate. His reactions are:



The relative importance of these two reactions can not, for obvious reasons, be stated. Both take place in nature. Probably in regions of hydrothermal activity the alteration to kaolin is more often found, while in regions of simple weathering the reverse is more often the case.

From the foregoing table it is seen that the soda content of basic is only slightly less than for acidic rocks. While the potash content of basic is about one-half that of the acidic rocks, the greater susceptibility to weathering of the basic rocks would lead us to conclude that the larger proportion of soda would be liberated from these rocks rather than from acidic rocks.

Lime and magnesia are liberated by decomposition but tend to pass into insoluble compounds more quickly than either potash or soda; consequently, we should expect to find them less abundant in salines.

The acid constituents of igneous rocks are relatively less abundant than the basic. Weathering would liberate these, and the abundance of oxygen present in the zone of weathering would convert the sulphur into sulphuric anhydride. This is also indicated by the comparative absence of reducing substances shown by the scanty vegetation of the basin. The chlorine, carbonic acid, and sulphuric acid would combine with whatever bases were present to form chlorides, carbonates, and sulphates.

The phosphoric acid, if liberated as soluble phosphate, would quickly pass into one of the many insoluble phosphates. Phosphoric acid is found in the salines only in small quantities and can not be considered as an important constituent of these substances.

Merrill, in discussing the decomposition of igneous rocks, presents the results of a number of studies and has endeavored to show what proportion of the original rock has been lost in the form of soluble compounds. It is evident that a mere comparison of analyses of weathered versus fresh rocks is inadequate. While it is generally true that the percentage of alkalis present in material resulting from weathering is less than the percentage in the undecomposed rock, still we have many examples where apparently the percentage composition has been unchanged, or the percentage of the alkalis has been increased. This is due to the fact that as the rock weathers its volume and weight change. If it were possible to determine the weight of fresh rock and the weight of residual material (soil) resulting from weathering, we could determine the proportionate loss of the constituents. This, for obvious reasons, can not be done. By assuming one constituent as constant, and that the most insoluble one, Merrill¹ has calculated the proportional loss of constituents due to weathering. From 10 examples of igneous rocks given by this author I have calculated the average percentage losses. The following table gives these for alumina, ferric oxide, lime, magnesia, potash, and soda:

Percentage loss of constituents from igneous rocks caused by decomposition.

Constituent.	Mean loss humid region. ²	Estimated for arid regions. ³	Ratio, humid- arid. ⁴
	<i>Per cent.</i>	<i>Per cent.</i>	
Al ₂ O ₃	14.17	7.8	1.8
Fe ₂ O ₃	32.84	13.2	1.8
CaO.....	66.9	5.3	12.6
MgO.....	64.7	10.4	6.2
K ₂ O.....	62.1	19.0	3.3
Na ₂ O.....	72.0	24.8	2.9

¹ Rocks, Rock Weathering, and Soils, p. 188. Merrill.

² Calculated averages from examples of igneous rock decomposition given by Merrill. Merrill's examples include granites, phonolites, syenite, diabases, basalts, diorites, and andesites. Rocks, Rock Weathering, and Soils, pp. 185-208, Merrill.

³ Calculated by dividing percentages of first column by ratios given in last column.

⁴ Calculated from data given by Clarke of average analyses of soils of humid and arid regions (Bul. 491, U. S. Geol. Survey, p. 467). Ratio is percentage of constituent in acid-soluble portion of soils from arid region divided by percentage of constituents in acid-soluble portion of soils from humid regions.

The results given are for humid conditions. We have no examples of a similar nature for arid conditions. A rough approximation may be made from the comparison of soils of arid regions with those of humid. Clarke¹ gives average analyses of a number of soils for both climatic conditions. From these we can obtain the ratio of one constituent in the average of soils from arid regions to the same constituent in average of soils from humid regions. These ratios are given in the foregoing table. If we assume that the proportional loss of a constituent from rocks in arid regions is the product of the proportional loss in humid regions and the reciprocal of the ratio, the results in second column of above table are obtained. No high degree of accuracy can be vouched for these results.

The following table has been calculated from the tables immediately preceding, and gives, perhaps, a better idea of the measure of igneous rock decomposition and the liberation of soluble constituents. The unit is taken as 100 pounds and only the more important bases and acids have been calculated. The acid constituents, with the exception of phosphoric acid, have been assumed to be entirely liberated.

Contribution from 100 pounds of original rock.

	Acid type.		Basic type.			Acid type.		Basic type.	
	Pounds constit- uent in 100 pounds.	Pounds contrib- uted by weath- ering.	Pounds constit- uent in 100 pounds.	Pounds contrib- uted by weath- ering.		Pounds constit- uent in 100 pounds.	Pounds contrib- uted by weath- ering.	Pounds constit- uent in 100 pounds.	Pounds contrib- uted by weath- ering.
MgO.....	10.50	0.156	4.52	0.470	S.....	0.370	0.370	0.066	0.066
CaO.....	2.15	.114	6.33	.335	Cl.....	.015	.015	.068	.068
Na ₂ O.....	3.35	.831	3.29	.816	CO ₂	.160	.160	.326	.326
K ₂ O.....	4.10	.779	2.09	.397	SO ₃	.035	.035	.....	.....
					F ₂ O ₃	.145	.....	.240	.....
Total..	10.65	1.880	16.23	2.018	Total..	.725	.580	.....	.460

SEDIMENTARY ROCKS.

The pre-Tertiary sedimentaries of the basin region are not important sources of saline material. Limestones are abundant and contribute to the lime compounds associated with salines. The gypsum deposits of the Triassic are and have been an important source of this compound. From Table X (Appendix), giving the average analyses of Great Basin rocks, it is seen that limestones contain 0.51 per cent alkalies. Merrill² shows that for weathering under humid conditions a limestone loses 63 per cent of the alkalies. If we take one-third of this as representing the conditions for an arid climate, we would have 21 per cent of 0.51, or about one-tenth of a pound of alkali per 100 pounds of fresh rock. The slates and quartzites contain small quantities of alkalies, but weather much less rapidly than either igneous or calcareous rocks. By their decomposition small amounts of bases are contributed to salines, but, on the whole, we must consider them far less important as a source of salines than other rocks.

The Tertiary lake beds constitute one of the most important sources of saline materials outside of the igneous rocks. They consist of limestones, shales, diatomaceous beds, slates, and sandstones. Interbedded and often commingled are salines of which common salt, sodium sulphate, gypsum, and boric minerals predominate. The disintegration of these beds liberates saline material, while the decomposition of the residual portion contributes an additional amount. As these beds are comparatively soft, they would erode rapidly, and, no doubt, in late Tertiary and Quaternary times they contributed a large proportion of the detrital filling of the present basins. The table following, showing partial analyses of lake-bed material, will give some idea of its chemical nature.

¹ Bul. No. 491, U. S. Geol. Survey, p. 467.
² Rocks, Rock Weathering, and Soils, Merrill, pp. 217-19; Mean of Percentages for K₂O and Na₂O.

Analyses¹ of material from lake beds northeast of Mina.

Constituents.	Sample No.—								
	1	3	4	5		7	8	9	12
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Insoluble residue.....	14.70	56.40	10.00	24.70	69.70	79.60	77.90	39.20	46.00
CaO.....	44.06	17.24	45.80	38.42	4.55	2.33	1.95	29.92	26.67
MgO.....	.58	.75	1.12	.40	2.55	.79	.76	.94	.54
K ₂ O (total).....	.24	1.12	.38	.46	1.81	3.08	1.91	.90	1.46
Na ₂ O (total).....	.25	1.47	1.23	1.28	2.50	3.00	5.47	2.05	1.54
Cl.....	.29	.18	Tr.	.19	.90	.49	.33	.12	.14

¹ Alkalies determined by Cullen; others determined by Young.

All except sample No. 1 contain traces of P; all contain acid-soluble Al₂O₃ and Fe₂O₃.

The samples were taken from different beds. My examination failed to show water-soluble carbonates and sulphates, and I found only traces of water-soluble potash. The principal soluble salt was sodium chloride. Other analyses of these lake beds have been reported and sodium chloride noted. The material other than that of a calcareous nature consisted of volcanic glass and tuffaceous particles of a volcanic nature. Microscopic examination showed much volcanic glass. The examination also indicated that most of the material, excepting calcium and magnesium carbonates, was of a wind-blown nature and had been deposited in shallow, brackish lakes in which calcium and magnesium carbonates were being laid down.

The Quaternary lake beds are of considerably less importance than the Tertiary. They contribute some saline material to the present drainage system, but as these beds are in the main sands and silts with little visible saline material, they may be regarded as of minor importance. Russell¹ reports lacustral material containing as much as 1.17 per cent sodium chloride. In this connection it should be noted that the material obtained from the 985-foot bore, sunk by the Geological Survey in Carson Sink through recent and Lahontan formations, failed to show any brines or solutions of marked saline content. Petrographic examination of Lahontan Lake bed sedimentaries shows comparatively little decomposition of the feldspars.

ALLUVIAL AND DETRITAL MATERIAL.

The heterogeneous material constituting the valley fills comprises more than 50 per cent of the whole basin area. As this material is in a more or less finely divided condition and is subject to the action of percolating waters, decomposition must be more or less active and a not unimportant amount of salines contributed to the present stream systems through the agency of underground and surface waters.

SPRINGS.

As has been shown in a previous chapter, numerous hot springs occur in the basin region. No very complete studies of these have been made, and comparatively few analyses have been reported. In the table which follows, I have summarized the analyses of some 16 such springs.

Analyses of hot spring waters.

Constituent.	A.	B.	C.	D.	E.	F.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cl.....	58.84	56.72	58.79	35.00	38.79	20.27
SO ₄	1.41	2.87	.94	4.58	14.25	34.19
S.....				.22		
CO ₂	.90	1.05	.61	5.08	None.	Trace.
B ₂ O ₃				8.91		
Na.....	33.15	34.78	30.38	30.35	31.04	29.78
K.....	3.19	3.33	3.76	3.79	2.69	.92
Li.....				.27	Trace.	
Ca.....	1.99	.91	4.90	.25	1.23	1.18
Mg.....	.24	.17	.40	.01	.04	.04
As.....				.12		
Al ₂ O ₃			.82	.01	.04	
SiO ₂	.28	.17	.20	11.41	11.92	13.62
Total solids on evaporation (parts per 100,000).....	100.00	100.00	100.00	100.00	100.00	100.00
	3,067	2,443	2,330	285	249.5	102.1

¹ Quaternary History of Mono Valley, 8th Annual Report, U. S. Geol. Survey, p. 307.

² Calculated as SiO₃.

Analyses of hot spring waters—Continued.

Constituent.	G.	H.	I. ¹	J. ¹	K. ¹	L. ¹	M. ¹
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cl.....	20.25	10.98	2.63	9.74	Trace.	47.93	47.53
SO ₄	32.97	15.13	4.04	6.96	8.21	11.25	8.15
S.....							
CO ₂	Trace.	27.97	23.84	18.08	25.6	.67	1.36
B ₂ O ₃							
Na.....	30.03	29.56	12.83	10.67	2.25	32.63	31.92
K.....	1.61	3.05	2.12	5.33	5.15	2.70	2.80
Li.....	Trace.						
Ca.....	3.10	2.84	5.96	5.34	11.11	2.48	2.10
Mg.....	.29	2.92	2.02	2.55	Trace.	Trace.	Trace.
As.....							
Al ₂ O ₃		.09					
SiO ₂	211.75	27.46					
	100.00	100.00					
Total solids on evaporation (parts per 100,000).....	118.3	206.9	99.2	43.2	62.0	44.40	428.0

¹ Analyses not complete. Percentages based on solids on evaporation.

² Calculated as SiO₂.

A. Water from hot salt spring near bathhouse, Silver Peak, Nev. R. Dole, Bul. No. 530, U. S. Geol. Survey, p. 16.

B. Water from hot salt spring at northeast end of marsh, Silver Peak, Nev. R. Dole, Bul. No. 530, U. S. Geol. Survey, p. 16.

C. Utah Hot Springs, 8 miles north of Ogden, Utah. Analysis by F. W. Clarke. Clarke, Bul. No. 491, U. S. Geol. Survey, p. 172.

D. Steamboat Springs, Nev. Analysis by W. H. Melville Clarke. Bul. No. 491, U. S. Geol. Survey, p. 175.

E. Hot Springs, Hot Spring Station, Central Pacific Railway. Analysis by T. M. Chatard, Russell, Monograph U. S. Geol. Survey, No. 11, p. 49.

F. Schaffer's Spring, Honey Lake, Nev. Analysis by T. M. Chatard, Russell, Monograph No. 11, U. S. Geol. Survey, p. 51.

G. Hot spring, near Granite Mountain, Nev. Analysis by T. M. Chatard, Russell, Monograph No. 11, U. S. Geol. Survey, p. 53.

H. Warm spring, Mono Lake. Analysis by T. M. Chatard, Russell, 8th Annual Report, U. S. Geol. Survey, p. 288.

I. Paradise Valley Spring, Nev. Analysis by J. A. Cullen. This spring contains hydrogen sulphide.

J. X L spring, Oregon Lake Region. Analysis by J. A. Cullen.

K. Hot springs, in Thousand Springs Valley, 30 miles northeast of Wells, Nev. Analysis by J. A. Cullen.

L. Boiling spring, 0.75 mile northwest of Gerlach, Nev. Sample by W. S. Palmer. Analysis by J. A. Cullen.

M. Mean analyses of 4 spring waters taken one-fourth mile northeast of Gerlach, Nev. Temperature of waters from 61° to 90° F. Samples by W. S. Palmer. Analyses by S. C. Dinsmore.

In three of these spring waters the total solids exceed 1,000 parts per 100,000 of water, or over 1 per cent. The highest of these contains some 3 per cent total solids. The remainder contain from 0.1 to 0.8 per cent total solids. In seven of these waters chlorides predominate, while in the others chlorides and sulphates are about equally divided. In three of the waters only are carbonates conspicuous. Bicarbonates are present in seven cases. The average ratio of sodium to potassium is 10.9. In three cases the sodium-potassium ratio is notably low. The lime, magnesia, and silica are generally low. In the case of the Utah Hot Springs and the warm springs of the Silver Peak district the lime content is high, while in the case of the Steamboat Springs and hot springs of the Central Pacific Railroad the silica is high. In only one case has boric anhydride been noted.

Hot springs contribute to the salines of the basin, but it is believed that their total contribution must be small, as the flow from such springs is in the aggregate not very large, while the saline content is usually quite small. Perhaps all the hot springs of the basin would not contribute an amount of saline material equal to that from a fair-sized stream. How important the contributions to saline material in past geological ages from this source were we can not conjecture.

QUATERNARY AND RECENT VOLCANIC ACTIVITY.

Extinct craters are not uncommon in the basin region. The centers in which these cones are to be found are Lassen County, in the vicinity of Mono Lake, and in the vicinity of Great Salt Lake. In these three localities many cones have been described. In the Carson Sink, Big and Little Alkali Lakes have been determined to be the craters of extinct volcanoes. Northeast of Blair, in the Silver Peak district, Nev., is a large cone. East of milepost 48 on the road between Goldfield and Rhyolite are two cones, while southeast of Rhyolite in Crater Flat is another. In Death Valley are evidences which point to the possible existence of recent vents. In Owens River Valley is also a cone. In addition to the volcanic cones many recent

(late Quaternary) lava flows, which undoubtedly originated from fissures, are to be noted.

While we have no evidence at present as to the amount and kind of saline material in the ejecta of these cones and fissures, from our knowledge of volcanic eruptions at present taking place we must conclude that a considerable part at least of the saline material at present in the basin came from volcanic sources. Chlorine, sulphuric acid, chlorides, and sulphur compounds are conspicuous in the gaseous and solid ejecta of volcanoes. Much of the chlorine that we find compounded with sodium undoubtedly originated from volcanic activity.

ATMOSPHERE.

From the atmosphere, important contributions of carbonic acid gas and, to some extent, chlorine, chlorides, and nitrogen compounds are being made. Wind erosion is undoubtedly responsible for the return of some of the saline material from the playsas to the mountain ranges.

REACTIONS IN THE ZONE OF WEATHERING.

REACTIONS OF SOLUTION.

The products of disintegration and decomposition in the zone of weathering may be divided into three groups—undecomposed rock fragments, partially decomposed rock fragments, and products of complete¹ rock decomposition. The last group may be divided into soluble and insoluble products. Of these the former would consist of alkalis and alkaline earths, together with acid radicals, chlorine, sulphuric anhydride, carbonic and bicarbonic, nitric, boric, and phosphoric; the latter would consist of kaolinite, muscovite, quartz, talc, zeolitic minerals, limonite, calcite, and chlorite. Between the alkalis and alkaline earths and the acid radicals certain important reactions would take place. The relative abundance and kind of bases and acid material would determine these reactions. The solubilities of the more important constituents are given in the following table:

Solubility of important constituents of decomposition product.

Basic element.	Chloride.	Sulphate.	Carbonate.	Bicarbon- ate.	Nitrate.	Borate.	Phosphate.
Sodium.....	Soluble.	Soluble....	Soluble....	Soluble....	Soluble....	Soluble....	Soluble.
Potassium.....	do.	do.	do.	do.	do.	do.	Do.
Calcium.....	do.	Insoluble..	Insoluble..	Soluble to slight extent.	do.	Slightly solu- ble.	Insoluble.
Magnesium.....	do.	Soluble....	do.	do.	do.	In solu- ble.	Do.

It is evident that in a system consisting of all chlorides and nitrates of the bases named all of the compounds would be soluble and only in the case of their concentrated solution would any salts separate out. It is apparent that the latter condition would rarely be present in the zone of weathering. In a system of chlorides, sulphates, carbonates, bicarbonates, nitrates, borates, and phosphates of sodium and potassium no reactions resulting in insoluble compounds could take place. In a system of chlorides and sulphates, lime would be the only base precipitated as a sulphate. This is indicated by the fact that gypsum is not an infrequent mineral in the zone of weathering, and its presence is no doubt due in part to reactions of this nature. The most common system that we find includes the chlorides, sulphates, carbonates, and bicarbonates of sodium, potassium, calcium, and magnesium. In this system calcium and magnesium would be thrown down as comparatively insoluble carbonates and calcium also as gypsum. We would expect the solution resulting to contain chlorides, sulphates, carbonates, and bicarbonates of sodium and potassium. In a system in which calcium and magnesium predominate we would expect to find mainly soluble chlorides, as all carbonic acid and sulphuric acid, except that required to saturate the system, would be thrown down by calcium and magnesium.

The analyses of waters coming from the zone of weathering invariably show small quantities of silica, ferric oxide, calcium carbonate, calcium sulphate, and alumina.

¹ The word "complete" is used in a restricted sense.

These are all compounds of very low solubility, and, as practically all are present abundantly in the zone of weathering, we may consider the solution as being saturated, or nearly saturated, with respect to these compounds. With the more soluble compounds it is unusual, except very locally, to have conditions in the zone of weathering which would lead to saturation.

Wind and water are the two agents concerned in the movement of the products of the zone of weathering. Even though the basin region has a scanty rainfall, water is by far the more important agent. Water dissolves the soluble constituents and carries away in suspension the finely comminuted products of disintegration and decomposition. Heavy rainstorms and cloudbursts carry down from the mountains quantities of comparatively coarse material to be deposited upon apron slopes or even in the central portions of the playas. One has but to walk over the detrital fans in Death Valley to appreciate the prodigious erosion that has been accomplished by cloudbursts. Ravines and gullies are choked with coarse débris, which spreads out in fan-like masses at their mouths and resembles more than anything else the piles of débris resulting from hydraulic mining. One has but to experience a dust storm in Death Valley, or any portion of the basin region for that matter, to appreciate the importance of wind as an agent of erosion and deposition.

ABSORPTION PHENOMENA.

In a previous section has been pointed out the importance of the seepage water and the fact that only a small part of the rainfall is collected in streams and reaches the sinks and lakes. This fact would indicate that under present climatic conditions only a fraction of the soluble salts is collected by the run-off, while the greater part is carried away by the seepage water to be in part permanently retained by the soil and in part to be removed by underground waters. Certain reactions take place within the soil and alluvial material and the soluble salts which are carried into the seepage zone by percolating waters. These reactions are to a greater extent chemical and to a less extent physical in nature. The net result is to withdraw a portion of the saline material permanently. The reacting substances are silicates and the colloidal material of soils, and in the solution, soluble salts of sodium, potassium, calcium, and magnesium. A solution of salts carrying more or less suspended material percolates into alluvial material. The suspended material is quickly removed and is concentrated in the upper layers of the soil. The phenomena attending the reaction between soil constituents and solutions are much more complex. Cameron¹ shows that absorption accounts for the removal of a part, at least, of the soluble salts. He groups under the term absorption the mechanical inclusion of solutions, the formation of new compounds by double decomposition, and the condensation of dissolved substances on or about the surface of the absorbing medium. To the last the term adsorption is given. E. C. Sullivan has summarized the literature dealing with adsorption, and from this summary the facts of special interest to this inquiry are taken.

The principal conclusions are embodied in the following quotations:

"So far as the evidence goes the action of silicates, clay, and other constituents of the earth's crust in solutions of such salts as do not dissolve in water with alkaline reaction consists in an equivalent exchange of bases. The salt is uniformly distributed between the water of colloid silica and silicates and the water of the solution. Any absorption of the salt as a whole by the solids mentioned is so slight as to have escaped positive detection. As bearing upon the latter point, it should be said that certain colloid substances, analogues to which are present in the earth's crust, do take from solution both the acid and base of the salts mentioned. Ferric and aluminum oxides and metastannic and stannic acids, for instance, take potassium sulphate from solution, while hydrated manganese dioxide takes up sulphate, chloride, or nitrate of potassium.²

"It may be observed that the base enters into reaction to approximately the same extent, whether it is combined as sulphate, chloride, or nitrate. So far as there is a difference, more of the base is removed from sulphate solution than from the others. On comparing chemically equivalent quantities, it is seen that ammonium is taken from solution in greatest degree, followed in order by potassium, magnesium, sodium, and calcium. As to the bases dissolved from the soil, Küllenberg's conclusion is that for the absorbed base nearly equivalent quantities of other bases, already present in the soil, have been carried over into the solution.³

"When the solution is alkaline in reaction, containing a soluble hydroxide dissolved as such or a salt made up of a strong base and a weak acid (as the carbonates, silicates, and phosphates of sodium and potassium), which is hydrolyzed by water with resulting formation of free alkali, its behavior with clay, soils, etc., is due largely

¹ The Soil Solution: Cameron, p. 59.

² Bul. 312, U. S. Geol. Survey, p. 27.

³ Ibid., p. 16.

to the presence of colloid silica or aluminosilicate, and consists primarily in the direct addition of alkali to these solids, without substitution, insoluble silicates or aluminosilicates being formed.¹

The loss of an acid radical of a dissolved salt to clay, soil, etc., appears, like the loss of the base, to be due usually to the formation of an ordinary insoluble salt, such

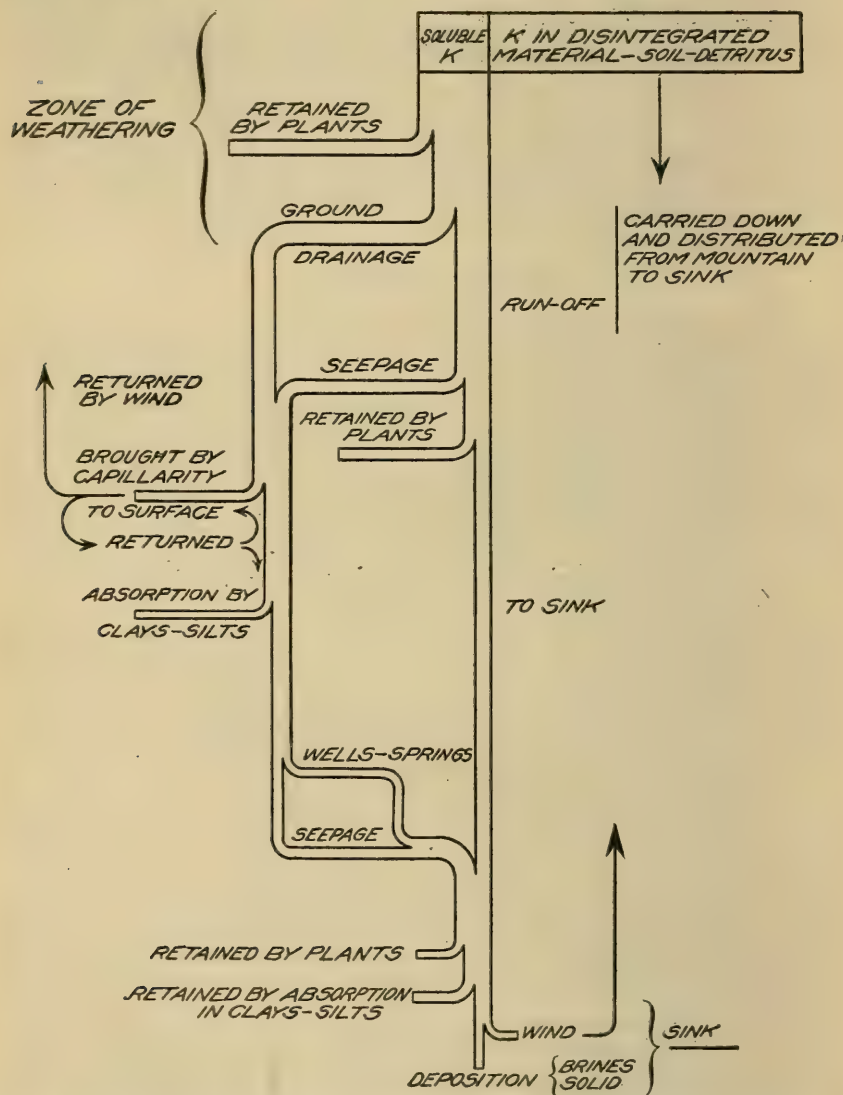


FIG. 2.—Diagram showing the factors of loss during the movement of a soluble salt from the weathering zone to the sink.

as the phosphate, carbonate, or silicate of calcium, iron, etc. Such precipitation takes place primarily from alkaline solution, because the acids that have the greatest tendency to form insoluble compounds are weak acids, whose salts are hydrolyzed by water.²

* * * Sodium silicates and aluminosilicates are less stable in contact with water solutions than the corresponding potassium compounds. Evidence of this is

¹ Bul. 312, U. S. Geol. Survey, p. 28.

² Ibid., p. 30.

found not only in the laboratory, but also under natural conditions. The replacement of sodium in silicates by the potassium of a dissolved salt takes place far more readily than the reverse reaction. A similar reaction, although perhaps not quite so marked, exists between magnesium and calcium silicates. The transformation of a magnesium silicate by calcium chloride into calcium silicate is more difficult than the reverse change."¹

The most significant fact of absorption phenomenon is the greater susceptibility of potassium to be absorbed than any of the bases and the greater resistance of potassium compounds to the action of percolating waters. The acid radicals, with the exception of carbonic, bicarbonic, and phosphoric, are unaffected in quantity.

The restricted and irregular rainfall of the basin region would result in more concentrated solutions being received by the seepage zone, and would result, therefore, in a greater relative amount of absorption than with the less concentrated solutions of humid regions.

A further fact must be kept in mind, and that is that a considerable part of the basin area receives such a scanty rainfall that only on comparatively steep slopes do the percolating waters reach ground-water levels and add their quota of soluble material to underground circulating waters. The greater part of the intermountain area acts like a sponge and receives and retains the waters and their dissolved salts. Capillarity raises a part of the water, together with such soluble material as escapes absorption.

Vegetation also plays an important part. It is a well-known fact that plants absorb potassium salts from the soil and seepage water. The amount of potassium removed annually in this way from ground waters must be large.

We are justified in the conclusions that in the basin region a large part of the soluble salts is retained in the interstitial or pore spaces of the soil; a part of the soluble material is changed to insoluble, and potassium is more likely to be retained and in greater relative amount than any of the other bases; a precipitation of the more insoluble carbonates, such as lime and magnesia, takes place in the upper part of the soil; that the stronger acids, such as chlorine, sulphuric anhydride, nitric, and boric (excepting sulphuric and boric in the presence of soluble lime salts) are practically undiminished by absorption phenomena. Combined with various bases they either remain in the soil or are leached away in the ground water.

Soluble salts reach the sinks or lowest parts of the intermountain areas in two ways—by underground waters which gravitate to the low points and by the run-off waters which accumulate in the same places. It is evident that in the passage of the seepage water to the sink absorption continues and only a final residuum, which may be only a small part of the original total of soluble salts, reaches the sink. The run-off waters are diminished on their way to the sink by seepage waters with consequent loss of a part of the dissolved salts. Figure 2 illustrates the various losses which we may expect in the movement of a soluble salt from the weathering zone to the sink. I have taken potassium as the base to best illustrate the point. The quantitative side of the problem can not be determined and consequently the figure does not involve this feature.

The case for sodium would be simpler than for potassium. Little or none of this base would be retained by plants or by chemical absorption, and the only loss would be that portion retained and brought by capillarity to the surface or retained simply by the soil. The greater part of the sodium, either as sulphate or chloride, would eventually reach the sink.

The case for lime and magnesia is also a simple one. Only that portion in the run-off waters would reach the sink. The remainder would be found distributed from and within the zone of weathering to the sink. The greatest part would be nearest the belt of weathering. A nominal amount would reach the sink through the agency of ground waters.²

¹ Bul. 312, U. S. Geol. Survey, p. 22.

² Calcareous hardpans are not infrequently found in the Great Basin. In the vicinity of Las Vegas, Nev., there is an especially good illustration of the development of a thick layer of calcareous material. This in some places forms the surface and in other places is covered by a thin soil. The rocks of the neighboring mountains are sandstones and limestones. An analysis of this hardpan shows the following (analysis by J. A. Cullen, Bureau of Soils):

	Per cent.
Insoluble.....	7.6
Ferric oxide and alumina.....	.46
Lime.....	37.20
Magnesia.....	12.65
Total potash.....	.30
Total soda.....	.39
Sulphate radical.....	.03

I have also noted many instances where the material of gulch dumps in the basin mountains has been cemented together by calcium carbonate.

In the alluvial fans it is not uncommon to find the material removed by the burrowing of small animals to be coated by calcium carbonate.

The factors influencing absorption are the rate of movement of underground waters, the concentration of solutions, the chemical nature of salines and salts, the distances to be traversed to outlet if spring, or to sink if there is no surface outlet. In the case of saline solutions retained locally the time factor is greatly increased and, consequently, absorption may proceed to practical completion. The conditions in any one case are so variable and the difficulty of definitely determining the quantities involved so great that we can not determine the extent of absorption. Evidence goes to show that potassium in some cases is almost completely retained. The comparison of underground waters with surface waters and the comparison of soils from humid and arid regions can, in a measure, be relied upon to show the character of the changes. The two succeeding sections deal with these subjects.

UNDERGROUND AND SURFACE WATERS.

In Table XI (Appendix) are given a number of analyses of well and spring waters from the Nevada experiment station records, obtained through the courtesy of S. C. Dinsmore. Accompanying are two tables, Nos. XII and XIII (Appendix), giving analyses of waters in Death Valley and Amargosa regions. The average ratios of sodium to potassium are as follows:

	Ratio.
Well and spring waters in western Nevada.....	43.1
Waters from Death Valley.....	47.4
Waters from the Amargosa.....	9.9
The Truckee, Humboldt, and Weber Rivers.....	3.6
The basin lakes.....	20.0

Seepage originates in part from run-off waters. The absorption of potassium would be indicated by a greater ratio of sodium to potassium in underground waters as compared to the run-off waters. This is indicated by the above ratios. The ratio for the basin lakes is intermediate between these for ground and surface waters. This is to be expected, since the lakes receive seepage as well as run-off waters.

SOILS OF HUMID AND ARID REGIONS.

Clarke¹ gives the average analyses of a number of soils from humid and arid regions. From these analyses the sodium-potassium ratio has been obtained and for purposes of comparison the same ratio for the igneous rocks of the basin is given.

Ratio of sodium to potassium in soils and rocks.

Ratio of potassium in—	
Humid soils.....	0.39
Arid soils.....	.31
Acid rocks.....	.78
Basic rocks.....	1.50
Mean, acid and basic.....	1.14

The figures obtained do not give a fair basis for comparison. In the case of the soils the sodium and potassium are determined in the solutions obtained by decomposition with hydrochloric acid. In the case of the analyses of the rocks the sodium and potassium represent the total percentage of each in the rock. If we assume that the insoluble residue obtained from the humid or arid soil would be of practically the same constitution the ratios would be of some value in indicating absorption. The arid soils show a greater proportion of potassium than the humid. If our assumption is correct, this is due to absorption. It may also be due to differences in the degree of decomposition. Comparing the soils with the rocks indicates the removal of sodium at a much greater rate in the weathering process than potassium. If we compare the percentage composition of the mean arid with the mean humid soil, we find the following interesting ratios:

Ratio arid to humid percentages of constituents soluble in hydrochloric acid.

Acid soluble:	
Soluble SiO_2	1.7
Al_2O_3	1.8
Fe_2O_3	1.8
MgO	6.2

¹ Bul. No. 491 U. S. Geol. Survey, p. 467.

Acid soluble—Continued.

CaO.....	12.6
Na ₂ O+K ₂ O.....	3.2
P ₂ O ₅	1.0
SO ₃	.8
Total acid soluble:	
Arid (per cent).....	29.5
Humid (per cent).....	16.0

These ratios indicate a much greater proportion of soluble material on the whole in the arid than in the humid soils. The greater proportion of soluble silica and acid soluble alumina would indicate more favorable conditions for the absorption of alkalis in the case of arid soils. The greater proportion of alkalis and alkaline earths indicates that absorption either by chemical reaction or by simple retention of soluble salts is a marked feature of arid soils.

While absorption by chemical reaction is of undoubted importance, absorption by retention of soluble salts is of much greater importance and is characteristic of the soils of the basin region. Whitney and Means state¹ that the soluble salts for soils of a sandy nature approximate 50 pounds per acre-foot (0.0015 per cent), for heavy soils from 3,000 to 4,000 pounds per acre-foot (0.09 to 0.12 per cent), and the average amount for soils of humid areas somewhat less than 1,000 pounds per acre-foot (0.03 per cent). Hilgard² states that very few of the upland soils in the arid regions of California contain less than 2,000 to 2,500 pounds of soluble salt per acre in the first 4 feet. In the soils of the lowlands the content of soluble salt must be considerably greater. No general numerical statement can be made for the soils of the basin region, but we know that in many cases the amount of soluble salts must be many times greater than that contained in the soils of humid regions. Table XIV (Appendix) gives the content and chemical composition of the soluble salts for a number of soils in the basin region. I have taken most of these from three widely separated localities. The first set are from soils in the vicinity of Fallon, Nev.; the second from soils in the vicinity of Salt Lake, Utah; and the third from southern Oregon. The average content of soluble salts for the Fallon soils is 1.23 per cent and for the Utah soils 1.8 per cent. It should be noted that the examples given are undoubtedly from localities more or less heavily impregnated with soluble salts. The average for the Fallon area can be obtained from figures presented in the advance sheets of the field operations of the Bureau of Soils, 1909.³ The content of alkali and the acres affected in each instance are given:

82,624 acres contain less than 0.2 per cent alkali.
 38,784 acres contain from 0.2 to 0.4 per cent alkali.
 8,768 acres contain from 0.4 to 0.6 per cent alkali.
 8,128 acres contain from 0.6 to 1.0 per cent alkali.
 12,096 acres contain over 1 per cent. The average content for 150,400 acres is 0.4 per cent.

While the results for the Fallon section can not be taken as representative of the basin region, still it can be said that they show the results for one important area. The conditions in other portions of the basin, and particularly south of the Fallon area, can not be much different. In fact, as we proceed south the evidences of soluble salts become more and more common. Many of the flat valleys which characterize southern and central Nevada show that the conditions are very favorable for the retention of the soluble salts. The physical conditions influencing the retention of salts by and their movement in soils merit some discussion and the succeeding section covers this subject.

RETENTION AND MOVEMENT OF SOLUBLE SALTS BY SOILS OF ARID REGIONS.

The factors controlling the retention of soluble salts are underground drainage, character of the soil, slope of soil surface, and rainfall. With good underground drainage, even under arid conditions, there is a gradual movement downward of the soluble salts. Underground drainage is dependent upon the character of the soil and the slope of the soil surface. With compact, heavy soils much seepage water is retained and drains away very slowly, or not at all. Capillarity acts in fine-textured soils to return the ground water, in some cases back to the surface, or in others to some intermediate level. With porous, open, and coarse-textured soils capillarity may act to a small

¹ Bul. No. 14, Bureau of Soils, p. 22.

² Bul. No. 35, Bureau of Soils, p. 13.

³ Soil Survey of the Fallon Area, Nevada, p. 43.

extent, but only very locally, and the seepage water drains speedily away. Where impervious layers occur, ground water may be retained and by evaporation leave its burden of salts within the soil at varying depths. Where soil surfaces are sloped, underground drainage is facilitated, and, if the soils are not too coarse textured, or capillarity not an important factor, the soluble salts are drained away and deposited in the level portions of the valleys.

With moderate rainfall salines are distributed in sandy soils with the least proportion at the surface and greater amounts or accumulations at intermediate points. Under arid conditions these accumulations would be nearer the surface, and in regions of extreme aridity would be very close to and even at the surface. With heavy soils (slow movement of ground water) the accumulations of salines would be nearer the surface for moderate rainfalls and much closer to the surface for small rainfalls than for the porous soils.

Means¹ discusses the conditions under which alkali salts move within the soil and his conclusions are pertinent here. He states that—

- (1) "Movement of alkali salts is caused by diffusion of the salt mixture;
- (2) "By the force of gravity in moving the salt mixture downward;
- (3) "By surface tension or capillary action which moves the salt mixture in any direction."

Means considers that the effects of the diffusion are practicably negligible. The second and third causes may best be placed in his words:

(2) "*Force of gravity.*—When water is applied to the surface of the soil the force of gravity, assisted by surface tension, pulls the water down into the capillary spaces. Soils will hold a certain percentage of water by capillary forces alone, and any excess over this percentage will drain away. This excess is called gravity water. When the surface of the ground is flooded, both surface tension and gravity act in pulling the water downward. Since the rate of flow of water through capillary spaces depends upon the size of the space, the flow through the large capillary spaces, root holes, worm borings, and animal burrows is very much greater than that through the true capillary spaces. When water is applied, the downward movement by gravity is almost entirely through the larger noncapillary spaces, while the true capillary spaces are filled by surface tension from the noncapillary spaces. In this way the salt which is dissolved by the descending water is probably to some extent drawn back into the capillary spaces, where there is very little downward movement, and remains there, only escaping out into the channels of downward movement by diffusion. The amount of salt which is washed downward by a heavy flooding is therefore not so great as would be expected.

(3) "The greatest movement of alkali salts is due to capillarity which operates through surface tension. When water moves by surface tension, the films around the soil grains move. As soon as the gravity water has drained away, the movements become entirely by surface tension. A loss of water due to evaporation changes the curvature of the water films and starts a capillary movement toward the point where the evaporation takes place. But when water moves by capillary action it is the water in the smaller spaces that moves, and not the water which is in the larger noncapillary spaces. Therefore the water which was drawn back into the capillary spaces and which carried some of the alkali salts as it flowed down into the soil starts upward and carries with it the salts in solution. The evaporation of an inch of water on the surface of the soil accumulates on the surface all alkali salts which were contained in that inch of water, while, on the other hand, the same volume of water leached down through the soil would probably not leach out an equal amount of the salts. From this it will be seen that the tendency of the alkali salts under irrigation is to move upward perhaps more rapidly than downward.

"From the above discussion it appears that surface tension or capillary attraction, as it is commonly called, is the most important agent in the movement of alkali salts toward the surface of the soil. Therefore, a soil which would permit the most rapid movements would be the most likely to accumulate alkali salts upon the surface. If two soils with different capillary powers were placed side by side, with the level of standing water the same, the soil which raised the water to the surface the more rapidly would the sooner accumulate an alkali crust."

THE POSITION OF MAXIMUM SOLUBLE SALT CONTAINED IN THE SOIL.

The following table summarizes certain observations which have been made concerning the depth at which soluble salts form accumulations.

¹ Bul. No. 35, Bureau of Soils, p. 13.

Depth of accumulations of soluble salts in soils.

3-inch rainfall, Imperial Valley, Cal.	8-inch rainfall, Fresno district.	12-inch rainfall, Yellowstone Park.	15-inch rainfall, Ventura County, Cal.	20-inch rainfall, Grand Falls, N. Dak.
In virgin soils greater part of soluble salts at a depth of 18 inches. ¹	Sandy loams 3 to 4 feet; coarse sands 4 to 8 feet. ¹	Heavy soils 4 to 6 feet; sandy soils 7 to 11 feet. ²	Bulk of soluble salts at 5 feet. ¹	Greater part of soluble salts below 3 feet. ¹

¹ Bul. No. 35, Bureau of Soils, p. 15.

² Bul. No. 14, Bureau of Soils, p. 27.

Two important actions take place in the movement of saline material in soils. Rainfall penetrates the surface soil and percolates down to certain depths. In its passage downward it dissolves a portion of whatever soluble salts may be present and thus leaches the material at the immediate surface. The extent to which this leaching would take place would be determined by the proportion of gravity water to water of capillarity and the penetration of the water. This is determined largely by the texture of the soil. With a porous soil this leaching action would be especially noticeable. In the leaching of a soil in the manner described above, it is evident that the more soluble constituents would be first dissolved and carried to the greatest depths. Underground water soon reaches a position of equilibrium which may be within the permanent ground-water level or within the zone close to the surface. Capillarity begins to act. The ground water moves toward the point at which evaporation takes place. It should be noted that when this water reaches its equilibrium position it has dissolved a large amount of salt. When the solution is returned by capillarity these salts are carried with it and deposited at the point where evaporation takes place. Capillarity may not return these salts to the surface, for evaporation may take place below the immediate surface, and the capillary water column may terminate at varying distances from the surface. The height to which the water is raised by capillarity would determine the position of accumulated salts. It has been shown in another place that where ground waters are deeper than 10 feet from the surface little or no evaporation from them takes place. This would indicate that ground waters at depths greater than 10 feet could not be concentrated by evaporation, and consequently there would be little or no opportunity for the separation of salines under such conditions.

NATURE OF SALINES IN SOILS.

Calcium, magnesium, sodium, and potassium are the bases almost invariably present. Sodium in almost every instance is the dominating base, while calcium and magnesium are usually the smallest in amount. Potassium is much less than sodium. In the Fallon soils sodium is 12.6 times potassium, while in the Utah soils it is 5.6 times. The acid radicals of chlorine, sulphur, carbon dioxide, nitrogen, and phosphorus are invariably present. Chlorides and sulphates usually predominate, although in some soils carbonates and bicarbonates are in greater abundance. The Fallon soils contain sulphates in greatest amount, while in the Utah soils chlorides are in greatest amount. Bicarbonates are usually present in greater amounts than carbonates. Phosphates and nitrates are present in most cases in traces, although in some exceptional cases nitrates may be present in appreciable amounts. Two Fallon soils showed over 2 per cent nitrate in the total solids. The basin soils would present many variations from the examples given. Borates, for instance, are common in many playas.

COLLECTION OF SALINES BY SURFACE WATERS.

RIVER AND LAKE WATERS.

Rivers being the main collecting agents for gathering salines from a given area and transferring them to the lakes and lake basins, the content and nature of the salines as well as the amount collected can be determined from the analyses of the river waters. It should be noted that the rivers receive a certain proportion of seepage water and consequently the chemical analysis reflects not only the nature of the salts collected from the weathering zone, but also the salts received from underground waters. It is to be regretted that analyses of composite samples taken from basin rivers over long intervals of time are not available. What analyses are given represent single samples. The results must be used with caution.

The lake waters represent the saline accumulations during present times. It should be noted that certain compounds are precipitating out continuously and consequently the composition of the waters represents an approach to equilibrium conditions for the particular time. Variation in climatic conditions results in the raising and lowering of lake levels. The fluctuation in lake levels, together with the continual acces-

sion of saline material, accounts for the variation in the analytical results often noted in the reports of analyses of lake waters of the basin. The fluctuations of lake levels would also produce a change in concentration and, consequently, the equilibrium conditions would be changed also. The more soluble salts are accumulating in these lakes while the more insoluble are precipitating out. The principal data concerning the chemical content of river and lake waters of the basin are given in Table XV (Appendix).

Much detailed chemical work has been done upon the California rivers by Van Winkle and Eaton,¹ and on account of the close proximity of this State to the basin region the results of their analyses are of importance. They are given in the table which follows:

Mean analyses, California rivers.

[Per cent of anhydrous residue.]

Constituent.	Humid (22 rivers); rain- fall, 15+ inches.	Semiarid (16 rivers); rain- fall, 15- inches.
	<i>Per cent.</i>	<i>Per cent.</i>
Cl.....	8.95	7.89
SO ₄	14.91	37.02
CO ₃	31.27	18.87
Na+K.....	12.53	12.34
Ca.....	15.52	12.83
Mg.....	5.37	5.76
Fe.....	0.12	0.02
SiO ₂	11.33	5.27
Solids on evaporation, parts per 100,000.....	100.00	100.00
	16.5	62.7

From the study of the results the following conclusions are of importance to the present inquiry: The total soluble salts in a river water under normal conditions varies with the stream flow. They are a minimum for a maximum flow and a maximum for a minimum flow. Normal conditions may be assumed to be those for a humid region. The components of the total salts also follow the above rule. If we take the Yuba River as an example and apply this rule to the various soluble constituents, we find that chlorine, the sulphate radical, carbonic acid, sodium, and calcium follow this rule. Potassium fluctuates; magnesium shows little fluctuation; silica remains practically constant. In an arid or semiarid region soluble salts tend to accumulate during periods of low water. When the first floods come the river water gains in total solids and sometimes to a very marked extent, due to the washing out of these accumulated salts. Certain rivers, such as the Santa Ynez and the Owens River, maintain the amount of total salts at practically a constant figure. Concerning the comparison of the mineral content of waters in semiarid and humid regions Van Winkle and Eaton state:

First. "The average mineral content of waters in semiarid regions is, roughly, four times that of waters in humid regions.

Second. "Difference in percentage composition of the anhydrous residues shows that the waters in semiarid regions contain about two-thirds the proportionate amount of silica, less calcium; four-fifths as much carbonates, and twice as much sulphates as the waters of the humid regions. Their constituents are similar in amount. In regions of abundant rainfall disintegration of rock material can not keep pace with solution, erosion, and chemical decomposition. The more soluble constituents of the rocks are rapidly removed as they become exposed to the action of water, and their total amount in a given quantity of the solvent water is seldom great. In arid or semiarid regions, however, chemical action is frequently less marked than physical disintegration. The soluble materials of the disintegrated rock masses accumulate through periods of drought, allowing the water from subsequent rainfalls to take into solution a greater relative amount than is found in waters from more humid regions.

"In the waters studied the average amount of mineral in streams from the semiarid regions was 627 parts per million; in rivers of the humid regions it was 165 parts per million. The greatest average mineral content, 2,412 parts per million, occurred in Santa Maria River, which flows through a sandstone country receiving barely 10 inches of rain a year. The smallest amount of mineral matter was found in Merced River, 65 parts per million, or about one-fortieth of the amount for Santa Maria River.

"As the silica content is apparently unaffected by the amount of the other dissolved constituents, it may be expected that the percentage of silica in rivers of high dis-

¹ Water-Supply Paper 237, U. S. Geol. Survey.

solved solids will be correspondingly low. This is true in California waters, the average silica for the humid-region rivers being 13.4 per cent and for the semiarid-region waters 8 per cent of the total mineral matter in solution. The principal effect, then, of climatic condition on silica content is a negative one and it is apparently due merely to change in total mineral content.

"By the decay of the abundant organic material in humid regions carbonic acid is set free, being dissolved in the surface waters or entering the air as carbonic dioxide. This carbonic acid, uniting with the carbonic acid of the alkaline-earth carbonates, produces the bicarbonates which are readily dissolved, so that surface waters in regions of abundant rainfall carry large amounts of the bicarbonate radical and of the alkaline earths. In regions of deficient rainfall, on the other hand, carbonic rocks are attacked to less extent and the gypsum and alkaline sulphates that are present are brought more largely into solution."

The conclusions of Van Winkle and Eaton may be applied to basin conditions. A somewhat different grouping of the basin rivers is desirable, and I have attempted this in the following. This grouping is not accurate, for the reason that some of the basin streams rise in the higher mountains and under conditions similar to many of the streams upon the western slope of the Sierras, while the lower courses of these streams are in the valleys and under semiarid or arid conditions. Three groups are made:

(1) Streams which have watersheds under humid conditions. These are Mill Creek, Leevining Creek, Rush Creek, the mountain streams tributary to Owens River, and the short streams of the higher ranges of the basin.

(2) Streams which have watersheds partly under humid conditions and partly under arid. These are the Truckee, Carson, Walker, streams tributary to Great Salt Lake, and streams tributary to the southern Oregon lakes.

(3) Streams which have watersheds under arid conditions. These are the Quinn, Armagosa, Humboldt, Reese, and Owens Rivers.

Streams of the first group are comparable to such rivers as the Yuba and the Tuolumne, and the California streams for humid conditions generally. Streams of the second group are comparable with the California streams under semiarid conditions. Streams of the third group are in a class by themselves, and, in the absence of detailed studies, can not be properly characterized.

The streams tributary to Great Salt Lake are characterized by high chlorine content, while the streams of the Lahontan Basin have a high sulphate content. Owens River is the only stream in which a noticeable amount of nitrates has been reported.

Lake waters are similar in composition to the river waters. There are some differences, and in order to show this I have worked out certain ratios which are given in the accompanying table.

Ratios between certain soluble constituents in lake and river waters.

Source of sample.	Na K	Ca Mg	Cl SO ₄	H CO ₃ +CO ₂ Cl+SO ₄
Rivers:				
Ogden.....	2.7	2.6	4.12	1.16
Weber.....	2.0	2.8	1.50	1.74
Bear.....		2.1	3.97	.53
Jordan.....		8.1	1.13	-----
Humboldt.....	4.6	3.9	.15	2.45
Amargosa.....	11.9		.52	.30
Walker.....		6.0	1.11	1.28
Truckee.....	2.2	3.2	.58	1.63
Owens.....		3.5	.56	2.35
		2.6	.61	2.42
Lakes:				
Great Salt.....	6.6	.14	9.29	-----
Winnemucca.....	18.9	1.10	12.73	.15
Pyramid.....	16.0	.10	7.81	.30
Humboldt.....	4.5	.70	9.73	.61
Walker.....		.56	1.11	.38
Mono.....	20.4	.40	1.81	.64
Owens.....	23.6	2.00	2.50	.70
Harney.....	18.6		3.50	.73
Abert.....	27.1		18.9	.54
Sevier.....		.04	4.8	-----

CALIFORNIA RIVERS.

Mean of rivers in semiarid region.....		2.51	0.21	0.83
Mean of rivers in humid region.....		2.88	.60	2.64

The sodium-potassium ratio has been discussed in another section. The calcium-magnesium ratio shows a marked decrease for the lake waters as compared with river waters. This can be explained by the fact that calcium readily precipitates as carbonate or sulphate, or may be removed by the agency of vegetable organisms¹. The removal of calcium would leave the magnesium in greater relative amount. There is no doubt that magnesium is also precipitated as a carbonate, but is not eliminated at as great a rate as calcium. Chlorides are more abundant than sulphates in the lake waters as compared with river waters. This is undoubtedly due to the precipitation of the sulphate radical by lime. Carbonates and bicarbonates are in less relative proportion in lake waters than in river waters. This is accounted for by the precipitation of calcium and magnesium as insoluble carbonates.

Borates are conspicuous in Owens, Mono, and the lakes of southern Oregon. The waters of Owens Lake are noteworthy on account of the content of nitrates and arsenic compounds.

Certain regional characteristics become noticeable in a comparison of the chemical content of lake waters. The lakes of the Bonneville Basin are conspicuous for their lack of carbonates and bicarbonates and their high content of chlorides. Sulphates are present, but in moderate amount. The high content of these lakes in salines is to be noted also. The regional rocks of the Bonneville Basin are, for the greater part, sedimentaries. Limestones are common.

The lakes of the Lahontan Basin have a much lower saline content, and contain chlorides, sulphates, and carbonates. Chlorides usually dominate, but in Pyramid, Winnemucca, and Humboldt Lakes carbonates are somewhat greater in amount than chlorides. The regional rocks are characterized by a greater area of igneous rocks than the Bonneville Basin.

Owens and Mono Lakes contain chlorides and carbonates in greatest amount. Chlorides are greater in amount than carbonates and sulphates are least. These lakes are characterized by a high saline content. The regional rocks are predominately igneous. The southern Oregon lakes are low in sulphates and have about equal amounts of chlorides and carbonates. In the case of only one lake are the chlorides exceeded by the sulphates. The regional rocks are igneous.

ANNUAL SALINE CONTENT OF RIVER DISCHARGES.

The rate at which salines are accumulating at present in the basin lakes can be calculated approximately from the mean annual flow of the principal rivers and their saline content. As has been mentioned before, the chemical data are insufficient, and, consequently, the conclusions give only approximate results. It is believed that the figures are conservative and rather under than overestimates. In Table XVI (Appendix) are given the tons of salines discharged by the Owens, Humboldt, Truckee, Walker, and Bear Rivers. The total salines discharged by these five rivers into their lake basins is 1,692,153 tons per annum.

An approximate determination has been made for four basins and is given in the accompanying table:

Discharge of salines into four important lake basins.

Basin.	Total run-off per annum for basin.	Rivers typical of run-off water.	Mean annual flow of these rivers.	Ratio of total run-off to flow of rivers.	Salines discharged per annum by rivers.	Total salines discharged per annum into basin.
	<i>Sec.-feet.</i>		<i>Sec.-feet.</i>		<i>Tons.</i>	<i>Tons.</i>
Bonneville.....	3,583	Bear.....	1,860	1.9	1,259,235	2,392,546
Lahontan.....	2,406	Walker, Humboldt, and Truckee	1,504	1.6	286,019	457,630
Owens.....	306	Owens.....	306	1.0	102,228	102,228
Southern Oregon lakes....	724	Truckee.....	1,030	.7	155,335	108,734

¹ Bul. No. 108, U. S. Geol. Survey, p. 94.

The total salines collected by the rivers of these four basins approximate 3,061,138 tons per annum. The contribution per square mile is given in the following table:

Quantity of salines collected by rivers tributary to four important lake basins.

Basin.	Area.	Quantity per square mile.
	<i>Sq. miles.</i>	<i>Pounds.</i>
Bonneville.....	49,500	96,600
Lahontan.....	40,000	22,880
Owens.....	3,200	63,800
Southern Oregon lakes.....	12,000	108,720
Average for four basins.....		64,800

¹ Estimated.

These figures represent the most active basins, excepting the one in which Mono Lake is situated. They may be taken as representing the northern and western parts of the Great Basin. The southern half of the basin must contribute a very much smaller amount of saline material to the sinks.

While the above figures appear large and may be large, still when compared with estimates from humid regions they do not appear unreasonable. Van Hise quotes the estimate of T. Mellard Read¹ for the amount of salts per square mile per annum for the whole globe as follows:

Total, 192,000 pounds. Of this total, calcium carbonate is 10,000 pounds; calcium sulphate, 40,000; sodium chloride, 16,000; silica, 14,000; magnesium carbonate, 8,000; iron oxide, 2,000. Clarke² quotes the figures of Dole and Stabler² for chemical denudation in the United States as 87 tons per annum per square mile. This would be 174,000 pounds and would apply to humid conditions. The figures given show that the chemical denudation in the more active parts of the basin region is equivalent to 37 per cent of this figure.

Table XVII (Appendix) gives the salines in pounds for each square mile of watershed for the Truckee, Walker, Humboldt, and Owens Rivers. For purposes of comparison I have added the figures for five rivers in California. The figures show the close relation between run-off and salines removed per square mile. While the saline content of the waters of a river in the semiarid region may be much higher than for a river under humid conditions, the total salines collected in a given time from a unit area is usually much less. This is easily explained by the fact that the greater proportion of the surface waters is absorbed by alluvial material and their salts are retained. The low yield of the Humboldt River is noteworthy. The very small run-off is sufficient explanation. In general, the figures presented show that the greater the run-off the greater the "crop" of salines from a unit area. Exception of the Kern River and the San Ysabel Creek may be made. The character of the watershed and the rate of decomposition of the regional rocks enter as a factor. The greater relative "crop" of these two streams is undoubtedly due to a greater rate of decomposition of the rocks, or a greater amount of salines in the disintegrated rock upon their watersheds. The water-duty factor, pounds of salines per square mile per second-foot per annum, gives a better basis of comparison between rivers under arid and rivers under humid conditions. Omitting the Kern and San Ysabel, since these streams have exceptional conditions upon their watersheds, the streams of the basin region show a much higher duty than those of the humid region in the near neighborhood. To put it in another way, the same quantity of water on the Owens River watershed would gather 4.5 times as much saline material as upon the Tuolumne, and 3.2 times as much as upon the Truckee.

The figures given can not be taken as the annual rate of chemical denudation for the basin, for it must be kept in mind that the basin streams gather only a part of the run-off waters, the remainder being absorbed in the sinks and basins. Expressed as an equation—Pounds of salines liberated per square mile=pounds of salines retained in soil and sinks+pounds gathered by rivers and discharged into lakes. No data upon the amount of salts absorbed are available and, consequently, the second number of this equation can not be quantitatively stated. The third number

¹ Treatise on Metamorphism, p. 486.

² Bul. No. 491, U. S. Geol. Survey, p. 103.

of the equation is the only one which admits of approximate quantitative statement, and figures for this have already been given.¹

Of the ions, sodium and potassium are of most interest. These constitute 19.4 per cent of the saline material. Potassium may be taken as 20 per cent of the combined weight of sodium and potassium. Applying these proportions to the 3,061,138 tons of salines for the four basins gives 593,860 tons of sodium and potassium, and 118,772 tons of potassium as the annual "crop" for approximately 95,000 square miles of the basin.

The figures given in the preceding represent the rate of accumulation under present conditions. The humid conditions of the Quaternary must have produced a much greater rate of accumulation than at present. The greater area of lake surface during Quaternary times would give less land surface for chemical denudation. For the Lahontan and Bonneville Basins it has been shown that for one unit of lake area there were 3.5 units of basin area. For the 95,000 square miles under consideration this ratio would give 74,027 square miles of land and 20,973 square miles of lake surface. If we assume that the rate of accumulation equaled the present rate for the Tuolumne River watershed, the above area of land surface would yield a "crop" of 13,650,000 tons per annum, or about four times the present rate of accumulation. While these results are no doubt crude, they at least give us some idea of the enormous amounts of salines that must have been discharged by the rivers of Quaternary times into the Quaternary lakes.

SALINE DEPOSITS.

To avoid repetition, this subject is presented under the following heads: Nitrates; Borates; Alum; Alunite; Crusts and Efflorescences; Playa Deposits; Deposits Resulting from Desiccation of Lakes; Buried Deposits of Salines; Salines in Present Lakes; Calcareous Deposits about the Shores of Present Lakes; Potash-rich Minerals; and Gypsum.

NITRATES.

Gale² has summarized the occurrence of nitrates in the Great Basin region. From his work I give below some of the principal facts.

Nitrates have been reported in Utah, in the vicinity of Marysvale, Monroe, and Greenwich Canyon, and Grass Valley; in Nevada, in the vicinity of Lovelock, in northwestern Washoe County near Leadville, and in the canyons bordering the west side of Railroad Valley; in California, in the vicinity of the Calico Mountains, in the region northeast of Salton, along the Amargosa River near Tecopa, and in the vicinity of Death Valley, Searles Lake, and Danby Lake. The compounds reported are potassium, sodium, magnesium, and calcium nitrates. Potassium nitrate is the compound most often found. The deposits are of three types—cave, playa, and as efflorescences. Most of the Nevada deposits are of the cave type. They occur as veins, stalactites, and crusts in deposits protected from the action of surface waters. In playas, the nitrates are mixed with other salines. Occasional efflorescences of nitrates are found. The deposit occurring south of Tecopa, Cal., and along the Amargosa is of this type. The nitrates of the basin region are either leached from the soils or originate from the decaying organic matter accumulating in the caves. Gale is of the opinion that probably a majority of the nitrate deposits result from the decomposition of bat or similar guano in caves, or crevices in the rocks.

Nitrates have been reported in small amounts in river and lake waters. Van Winkle and Eaton report the nitrate radical in 18 river waters out of some 30 examined in California. The average content for the Owens River is 1.7 parts per million. This is equivalent to 0.5 per cent of the anhydrous residue. A more extended search for this radical would, no doubt, show it present in small amounts in most of the river waters of the basin. The origin of nitrate in river water is due to the leaching action of rain water on soils. Owens Lake contains 948 parts per million of nitrate radical.³ J. G. Smith reports traces of nitrates in all the waters from the southern Oregon lakes which he examined. I have no doubt that this radical, in small amounts, could be found in other basin lakes. In the analysis of the soluble material of basin soils

¹ The mean annual run-off for the basin region was approximately determined to be 1.06 inches of rainfall. If we assume the saline content to be 62.7 parts per 100,000 (the mean saline content of California rivers for semiarid conditions), the saline content in the run-off from 1 square mile is 96,251 pounds. This approximates the figure obtained for the Bonneville basin. On this basis the annual crop of salines for the whole basin would be 10,105,200 tons. The playa, silt and lake area is about 30 per cent of the basin area or 63,000 square miles. The concentration of the annual crop of salines on this area would give 164 tons per square mile or a surface crust 0.0012 of an inch thick.

² Bul. No. 523, U. S. Geol. Survey.

³ Water-Supply Paper No. 237, p. 122.

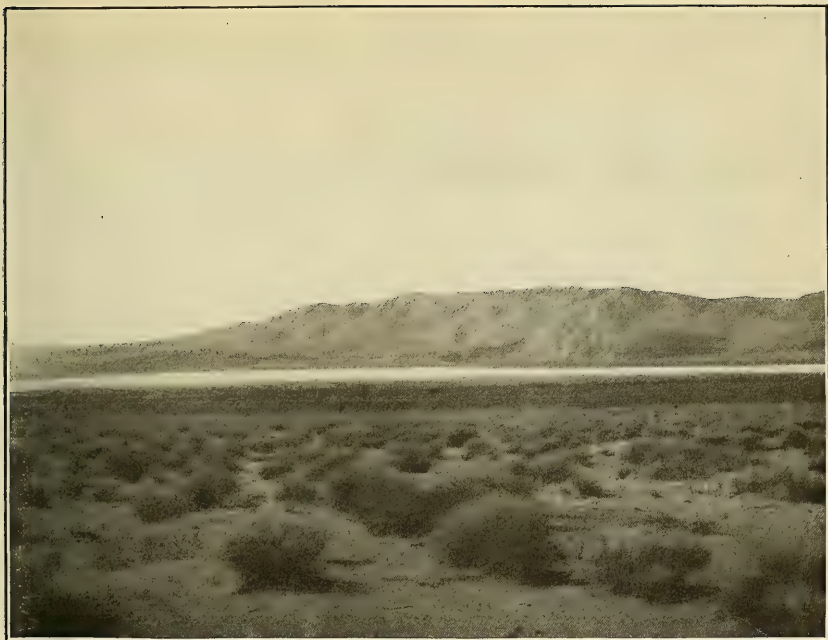


FIG. 1.—TEELS MARSH, NEV. VIEW LOOKING SOUTHWEST. TYPICAL SMALL BASIN.

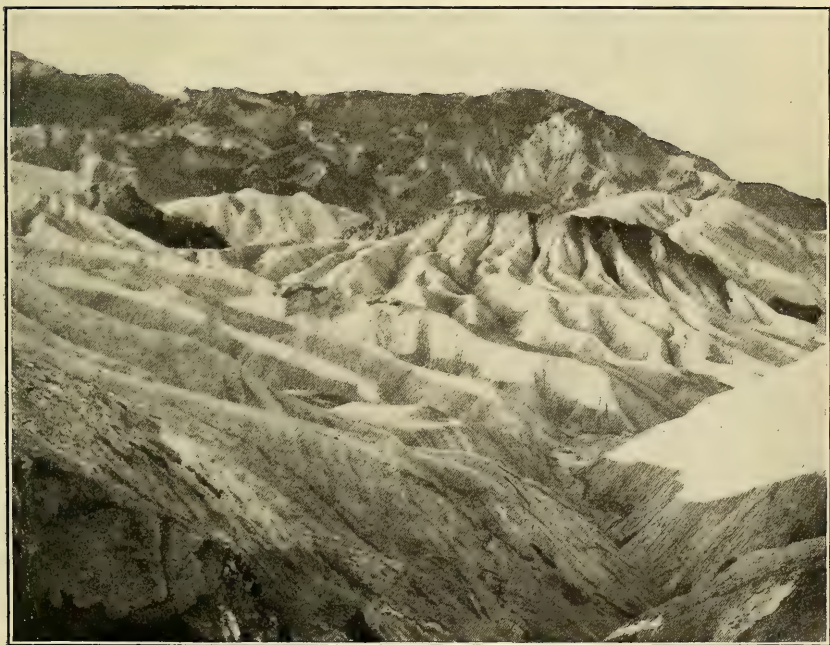


FIG. 2.—DEATH VALLEY, CAL. EROSION OF TERTIARY BEDS SOUTH OF FURNACE CREEK AND EAST OF THE VALLEY. BLACK MOUNTAINS.



FIG. 1.—ROUGH SALT AREA, DEATH VALLEY—EAST SIDE; EAST OF BENNETTS WELLS.



FIG. 2.—SMOOTH SALT AREA, DEATH VALLEY—EAST SIDE; EAST OF BENNETTS WELLS.

nitrate from traces to appreciable amounts has been shown. No deposits of economic importance have as yet been discovered in the basin region and the outlook for any important discovery in the future is not promising.

BORATES.

Borates occur in many localities in the basin region; in fact, they may be said to be found in the western half of the basin region from Oregon to the Mojave Desert. There is a conspicuous lack of borates in the eastern half of the basin, although traces of boric acid have been reported in the analyses of the waters of Great Salt Lake.¹ While the borate radical has not been reported in river waters, there is no doubt that it exists in most of the basin streams in minute quantities. The borate radical has been reported in Harney, Mono, Large Soda, Summer, Fossil, Christmas, North Alkali, Middle Alkali, South Alkali, and Abert Lakes. In most of these lakes it is present in very small amounts, but in Mono, Owens, and Large Soda Lakes it is present in quantities ranging from 16.37 in Mono to 29.91 parts per hundred thousand in Owens Lake. It has been reported in the waters of hot springs. The water of Steamboat Springs, Nev., contains 21.7 parts per hundred thousand boric anhydride. A more detailed examination of the waters of hot springs in the basin region would undoubtedly show many other examples of the presence of borate minerals. Borates are discharged into lakes by river and seepage waters.

The workable deposits of borax are of two types—the marsh, playa, or dry-lake type, and the bedded deposits. The former occur in Rhodes, Teels, and Columbus Marshes, Nev.; in basins along the Amargosa River, in Death Valley, Saline Valley, and Searles Lake, Cal.; at Sand Springs and Fish Lake Valley, Nev.; and in the district immediately south of Alvord Lake, Harney County, Oreg. The latter occurs at Furnace Creek, Ryan, and at Borate, in the vicinity of Dagget, Cal. The bedded deposits are found in Tertiary lake beds.

The playa deposits have many features in common. They occur usually as peripheral deposits about the sink of an inclosed basin. They are formed by the action of drainage waters dissolving the borate minerals from the alluvial material surrounding the sink. Where the drainage water strikes the more or less impervious silts of the central part of the basin, it is deflected toward the surface and if it accumulates sufficiently to reach the zone of surface capillarity it is drawn to the surface and by evaporation leaves the soluble salts as surface incrustations and efflorescences. These salts accumulate and in time form workable deposits. The crusts are scraped up and hauled to treatment plants in which the crude borax is separated from mechanical impurities and associated salts. The deposits are slowly renewed. This fact is well illustrated by a series of analyses of crusts taken from Searles Marsh and given in the following table:

Analyses of renewed efflorescences of borax at Searles Lake.¹

Constituents.	6 months.	2 years.	3 years.	4 years.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Sand.....	58.0	55.4	52.4	53.3
NaCO ₃	5.2	5.0	8.1	8.0
Na ₂ SO ₄	11.7	6.7	16.6	16.0
NaCl.....	10.9	10.0	11.1	11.8
Borax.....	14.2	12.9	11.8	10.9

¹10th Annual Report, Cal. State Mineralogist. Analyses by C. W. Hake.

Deposits of this character derive their borate minerals from alluvial material. The disintegration and erosion of the Tertiary lake beds account for a part, at least, of the borate in the alluvial material of a number of the deposits mentioned above. The general prevalence of volcanic rocks and evidences of late volcanic activity may well account for the remainder.

Recent deposits of borax at depth are shown by the borings in Searles Marsh. The borate minerals are associated with other salines. They have been found not only in the marginal portions of the sink, but also in the central part. C. E. Dolbear² presents analyses of the material taken from two borings—the first, within the central

¹ Bul. No. 491, U. S. Geol. Survey, p. 144.

² Eng. and Min. Jour., Feb. 1, 1913, p. 260.

area of the sink; the second, on the outside margin. In the first boring borax is shown in percentages ranging from 1 to 5.5, and at depths extending from 18 to 50 feet. Below this depth traces of borax occur, while in the material extending from the surface to 18 feet practically no borax, or only a trace, was found. In the second, borax was reported in percentages ranging from 5.56 to 6.57 and extending from a depth of 30 to 45 feet. Above and below these depths only traces of borax were reported. The results of these borings would indicate that in some of the playas, at least, might be expected concentration of borax minerals at depth.

The minerals reported from deposits of the playa type are borax (sodium borate), ulexite (sodium calcium borate), and colemanite (calcium borate). The content of the crude material ranges from 5 to 20 per cent boric acid. Deposits of this type are no longer of economic importance.

Deposits of the second type are the important sources of borate minerals. In the basin region they are worked at Ryan and in the vicinity of Furnace Creek (Mount Blanco). For a description of these deposits the reader is referred to Campbell¹ and to Keyes.²

These deposits are of importance in that they account for the source of a part, and perhaps the principal part, of the borate material in certain playa deposits, notably those in Death Valley and along the Amargosa River. Of the bedded deposits Keyes describes two general types. The one is illustrated by the mines northwest of Dagget, Cal. In this locality the borate minerals are found in a finely divided state in beds of blue clay. The workable beds contain from 10 to 12 per cent boric acid. The other type is characterized by nodules and masses of almost pure colemanite in clays and shales of Tertiary age. Respecting the origin of these deposits, Charles Laurence Baker,³ after discussing the possible formation of the deposits by the evaporation of a body of water of considerable depth, presents the following:

"The alternative hypothesis that these minerals had their immediate origin in hot springs and solfataras opening directly into shallow lakes, perhaps only of seasonal duration, or in playas, has much to commend it, especially when considered in connection with the numerous evidences of shallow water deposition. These evidences comprise ripple marks, sun cracks, and rain prints, which are found on the finer as well as the coarser beds, and the layers of finer breccia and conglomerates interbedded with the fine shales and tuffs. Shallow lakes or ponds probably existed at times during the deposition of the fossiliferous tuff member, for they seem to be necessary to account for the presence of the gasteropods. The paucity or absence of fossils in the borate and the fine ashly and shaly tuff members, as well as the presence of the colemanite, limestone, and gypsum layers, apparently indicates the salinity of the waters.

"There was great volcanic activity before and during the deposition of the Rosamond. The larger fragments of lava were most probably derived from flows subject to erosion somewhere in the area tributary to the basin of deposition. Interbedded flows of both acidic and basic lavas make up a part of the Rosamond. But the fine volcanic ash was probably blown in by the wind or settled during explosive volcanic outbursts and need not have come from the immediate vicinity. The common view of the origin of calcium borate from solfataras and hot springs associated with the abundant contemporaneous vulcanism is likely to prove to be the correct explanation for the borax beds in this region."

I am in accord with the main points in Baker's view. It must be noted, however, that in the colemanite deposits of the type exemplified by Mount Blanco a considerable amount of secondary action is noticeable. There are many distinct veins of colemanite associated with the layer beds. One gets the impression that these are anything but bedded deposits. I am inclined to the view that the Mount Blanco deposits represent the solution of the borate minerals from beds and their concentration in more or less open fissures in close proximity as veins.

ALUM.

Spurr⁴ reports a deposit of alum and sulphur 10 miles north of Silver Peak, Nev. The area in which this mineral occurs is about 200 feet in diameter. The alum is associated with sulphur in rhyolite. It forms a network of small veins in the broken rhyolite. The rhyolite is intrusive in Tertiary sedimentaries. The mineral is a pure potash alum, kalinite. Spurr considers that the alum results from the action of steam and sulphuric acid emitted from solfataras. The acid attacks the potash and alumina of the rhyolite and forms kalinite.

¹ Bul. No. 200, U. S. Geol. Survey.

² Borax deposits of the U. S., Trans. Am. Inst. Min. Eng., vol. 40, p. 674.

³ Bulletin of the Dept. of Geology, Univ. of Cal., 6, p. 358.

⁴ Professional Paper No. 55, U. S. Geol. Survey, p. 157.

G. I. Adams¹ describes a similar deposit at the Rabbit Hole Sulphur Mines, Nevada. Instead of kalinite, alunite is the mineral formed in association with sulphur. Sol-fataric action is considered the cause of the formation.

Several samples were submitted to the cooperative laboratory from what was called a hot-spring deposit occurring 30 miles northeast of Wells, Nev., in Thousand Springs Valley. The mineral contained crystals of kalinite, sulphur, and gypsum. The two samples showed the following analyses:

Number.	K ₂ SO ₄ , Al ₂ (SO ₄) ₃ .	Ca SO ₄ .	Fe ₂ (SO ₄) ₃ .	S.	Na ₂ SO ₄ .	NaCl.	Insol.	H ₂ O.
319-1.....	40.06	18.20	Tr.	Present.	Tr.	Tr.	8.94	33.50
319-2.....	2.35	15.74	Tr.	Present.	Tr.	Tr.	75.28	5.10

The determination was made upon the water-soluble material in both samples. A test for alunite gave negative results. The richer material contains 57.14 per cent kalinite. The sample of water from the hot springs in the near vicinity gave the following results:

Analysis of water from hot spring.

	Percent.		Percent
Ca.....	11.1	SO ₄	8.2
Mg.....	Trace.	HCO ₃	52.2
K.....	5.1	Total solids on evaporation (parts	
Na.....	2.2	per 100,000).....	62.0
Cl.....			

The evaporation of a water of this composition would account for the potassium and alum in the surface deposit of the spring.

Undoubtedly there are other occurrences of alum. No attempt has been made to exploit deposits of this nature. Systematic sampling to determine the average alum content and the total tonnage available has not been made in any one case and, consequently, the value of such deposits is an open question.

ALUNITE.

Gale has described the occurrence of alunite in the Great Basin, and for a detailed presentation the reader is referred to his bulletin.² This mineral has been reported from the following localities:

Goldfield, Nev.; associated in soft, massive form in ores, and occurs also as a constituent of altered volcanic rocks. Kalinite is conspicuously associated with it.³

Cactus Range, south of the Goldfield-Cactus Road; associated with silicified rhyolite.⁴

Cuprite, 12 miles south of Goldfield; associated with an altered rhyolite pumice.⁵

Rabbit Hole Sulphur Mines, 35 miles northwest of Humboldt House, Nev.; associated with sulphur in Tertiary sedimentaries. The rocks are much silicified in the neighborhood of the sulphur deposits.⁶

Camp Alunite, 22 miles southeast of Las Vegas, Nev.; associated with altered andesites and monzonites.⁷

Las Vegas, locality 15 miles south of Las Vegas, Nev.; sample of alunite submitted by J. A. Delameter, who reports no name for the district, and states that there is apparently a considerable quantity of the mineral. The mineral submitted is massive alunite and contains 8.98 per cent potash.⁸

Marysvale, Utah, Little Cottonwood Canyon, 7 miles southwest of Marysvale. The alunite occurs in veins. The main vein has been traced for a distance of 3,000 to 3,500 feet, and reaches a thickness of 20 feet in the widest portion. The potash content is from 10 to 12 per cent. A parallel vein 6 feet wide occurs close to the main vein.

A review of the conclusions of Ransome, Butler, Adams, and Hill concerning the genesis of this mineral has resulted in the following summation: The occurrences of alunite may be grouped in two general types—those in which alunite was formed from the action of solfataric waters or vapors carrying sulphuric acid upon igneous rocks

¹ Bul. No. 225, U. S. Geol. Survey, p. 497.
² Bul. No. 511, U. S. Geol. Survey.
³ Professional Paper No. 66, U. S. Geol. Survey, p. 108, Ransome.
⁴ Bul. No. 308, U. S. Geol. Survey, p. 48, Ball.
⁵ Professional Paper No. 66, U. S. Geol. Survey, Ransome.
⁶ Bul. No. 225, U. S. Geol. Survey, Contributions to Economic Geology, p. 500.
⁷ Eng. and Mng. Jour., Dec. 19, 1908, p. 1293.
⁸ Records of the Cooperative Laboratory, Reno, Nev.

rich in potash, and those in which solutions rich in sulphates and coming from deep-seated sources rose through fissures and deposited their mineral content where temperature and pressure conditions favored deposition. In the first type the alunite has been deposited more or less *in situ*. In the second, the alunite originated at depth and was deposited close to the surface. Deposits of the first class are disseminated, while in the case of the second type the deposits are concentrated. To the first type belong the Goldfield, Camp Alunite, Rabbit Hole Spring, Cactus Range, and Cuprite occurrences. To the second belong the Marysvale occurrences. Alunite is a possible source of potash.¹ Of the known occurrences of this mineral in the basin region, the Marysvale deposit is the only one which shows possibilities of commercial exploitation. The results of work upon this deposit will be looked forward to with interest. In view of the widespread solfataric action, in past as well as present geologic periods, it is not improbable that other deposits of alunite will be discovered in this region.

ALKALI CRUSTS AND EFFLORESCENCES.

It is difficult to draw a sharp line between deposits of this type, playa deposits, and deposits resulting from the desiccation of lakes. I have included under this head, however, all surface deposits which have originated during present times and which are of inconsequential thickness. These deposits have their origin in the evaporation of shallow bodies of rain water, or in the action of seepage waters in bringing dissolved salts to the surface, either by springs or capillarity. Hot springs are also responsible for crusts in their immediate vicinity.

These occurrences are usually characteristic of the playas or sinks. In Table XVIII (Appendix) are presented analyses of crusts taken from a number of localities. The average of these analyses shows the ions in the following order: Na, 30.23; Ca, 2.29; K, 1.68; Mg, 1.38; and the acid radicals SO_4 , 30.39; Cl, 21.64; HCO_3 , 6.22; CO_3 , 6.13. The average analysis shows the predominance of sodium. The ratio of sodium to potassium is 19.1 to 1. The sulphate radical is in excess of the chlorine. Carbonates and bicarbonates are usually present and in a few cases are in large excess of chlorides and sulphates. Sodium chloride and sulphate are the two compounds most abundant. Potassium is usually small in amount, although in a few of the Utah crusts this element is present in percentages ranging from 3 to 6.

In Table XIX (Appendix) are given a number of analyses of salt crusts and waters from Railroad Valley, Nev. The samples were taken by E. E. Free and J. Hance. They were analyzed by A. R. Merz for the percentages of soluble salts and the potash content of the soluble salts. The samples represent a general survey of this area. They show, on the whole, a high content of potash. Six crusts and one brine were analyzed by J. A. Cullen, and his results are given in Table XX (Appendix). They show that sodium chloride is the compound most abundant, with potassium chloride usually next, followed in order of abundance by sodium sulphate, sodium bicarbonate, sodium carbonate. The average ratio of sodium to potassium is 5.7 to 1. The presence of potassium compounds in these crusts first attracted attention to this area and led to the exploratory work done by the Railroad Valley Saline Co.

The origin of salines of this nature is simple. They may be said to be derived from the weathering of rocks and the liberation of contained salines in the drainage area of the tributary basin. Through the agency of surface and underground waters they are collected in low places.

Such deposits, excepting the borates, which have been discussed previously, have no commercial value. The complex mixture of salts and the superficial nature of the deposits are the reasons for nonexploitation. In a few local cases salt has been gathered from crusts of this nature and marketed. No serious proposal has been made, as far as I am aware, for the exploitation of alkaline crusts rich in potash, although the aggregate amount of potash in an area like that of Railroad Valley must be very large. The chief interest in these deposits lies in the insight which they give into the chemical nature of the salines at present accumulating in the arid basins of the Great Basin.

PLAYA DEPOSITS.

Perhaps one of the most common topographical features is the desert basin. The basin may be circular, elliptical, or greatly elongated on one axis, forming a long, narrow valley. Such basins usually have in their lowest part a level area devoid of vegetation, sometimes covered with saline crusts, but more often simply consisting of a rain-puddled sheet of clay. To this central portion the term "sink" or "playa"

¹ For the conditions under which potash is made available in alunite see Cir. No. 70, Alunite as a source of Potash, Bureau of Soils, U. S. Dept. of Agr. For use of alunite as a fertilizer see Cir. No. 76, Alunite and Kelp as Potash Fertilizers, Bureau of Soils, U. S. Dept. of Agr.

is applied. The sink serves as a reservoir for the basin which it occupies. Naturally, it also serves to receive whatever soluble material is brought to it by surface or underground waters. As a consequence, playas may be looked upon as favorable places for the accumulation of salines. In order to present more clearly the nature of playa deposits, I have sketched the structural development of a desert basin.

STRUCTURAL DEVELOPMENT OF A DESERT BASIN.

The adjustment of the fault blocks of the Great Basin initiated a period of erosion, with its consequent deposition of detrital material in the intermountain areas. Flanking the mountains first appeared steep sloping aprons, or talus slopes. The finer sands and gravels were deposited in a wider zone at the foot of the apron area, and in the central portions the finest silts and clays were deposited. During this period shallow lakes no doubt occupied many of the basins. As erosion proceeded finer material was brought down and the mountain aprons assumed a less taluslike appearance. The sand and gravel aprons extended out and encroached upon the silt area and sufficient silt was brought down to fill the central basin and in some cases to obliterate the shallow lakes occupying them. Were lateral streams the only agents of transport, we should have a very definite structure revealed by the basin. A cross section of such an ideal basin would show a wide, level, and relatively thin body of fine silts and clays, flanked on either side with masses of detrital material rising in long, sweeping grades to the steeper slopes of the mountains. A gradation from fine sands to coarse angular debris mixed with material of all sizes would be noticed in passing from the central portions of the playa to the steeper mountain slopes. Figure 3 illustrates the section described. Under the conditions indicated above we should expect the central mass A to be characterized by little movement of ground water, while the flanking masses B and B would be zones in which ground waters could

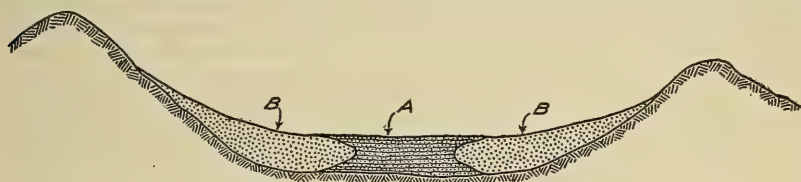


FIG. 3.—Ideal cross section of a desert basin.

actively circulate. With the progress of time, we should expect the apron slopes to flatten and the silt and clay area to extend laterally until a shallow, panlike basin would result. Surface waters would accumulate and shallow lakes would form in the rainy season. The impervious bottom of this lake would protect the waters from loss by seepage. The evaporation of these lakes would leave surface accumulations of salts which would receive fresh accessions each year until deposits of appreciable thickness would make their appearance.

Water is not the only agent which acts. Wind erosion and deposition also plays an important part. Under the influence of this agent the central portion A of the basin would not be composed of a homogeneous mass of clay and silts, but we should expect to find its homogeneity disturbed by layers of sand, volcanic ash, or other wind-blown material. Such beds would be continuous in a large measure over basin areas occupied by shallow lakes, but in the case of the ordinary playas conditions would not be favorable for the deposition of wind-blown material in thin beds. Upon the dry playas we should expect to find the fine silts of the central portion more or less eroded by the wind and deposited over the outwash slopes, or in certain portions of the basin as dunes. It is not an uncommon thing to find in a playa area one or more portions occupied by sand dunes of considerable extent. Another point should be mentioned, and that is that in periods of excessive rainfall or during cloud-bursts the streams would be so increased in volume as to carry out upon the central silt area sand and gravel. In this way tongues of coarse material would be formed in the silt portions and would form beds in which ground water could circulate. A perennial stream entering one end of a basin would effect a somewhat similar structure, but on a much greater scale.

The width of the intermountain spaces and the height of the inclosing mountain ranges would determine the proportion between the silt and detrital masses. With narrow valleys and high mountain ranges we should expect the outwash slopes to meet or even overlap at the center. As the valley filled a mass of silt of triangular section would be formed in the central part. Figure 4 illustrates this structure.

Some basins are characterized by having the silt area on one side of the intermountain space. This is caused by a difference in elevation of the mountain ranges and a difference in climatic conditions. The higher mountain ranges command a greater rainfall. We would therefore expect that greater erosion would result from the higher mountains than from the lower. This would result in apron slopes of greater extent from the sides of the higher mountains than from the lower. This would place the silt area close to the lower mountain range. Figure 5 illustrates the structure.

The ground-water conditions in basins of the types illustrated are worthy of further comment. In the case of figure 3, and assuming a region of inconsiderable rainfall, we should expect that the ground-water accumulations in B portions would be smaller and found at relatively great depths. The silt mass would retain its moisture close to the surface and lose it by evaporation. Capillarity would draw up the moisture together with any soluble salts for a depth of 10 or possibly more feet from the surface. At the central mass, built up by silt, or wind deposition, we would expect the soluble

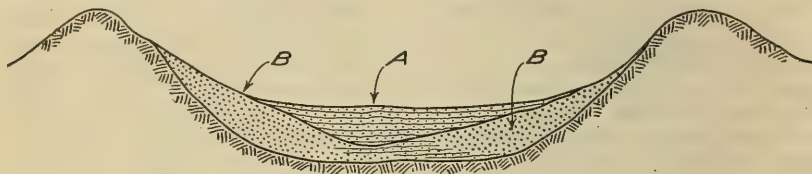


FIG. 4.—Cross section of a basin occupying a narrow valley between high mountains.

salts to be drawn upward and to remain as a conspicuous surface feature. Only on the edges of the silt portions would we expect to find any buried salt crusts and these would be distributed irregularly and be comparatively thin. In the case of a moderate rainfall we should expect an accumulation of ground water in B portions and the level of this ground water would reach the surface on the periphery of the silt mass. It would appear as spring water in the coarser material and as seepage water in the finer and more compact marginal portions. Under conditions of this kind we should expect the marginal portions of the silt mass, if not the entire silt mass, to be saturated with moisture. If the amount of this water, plus the rainfall on the playa area, would be sufficient to replace the evaporation losses, a lake might be expected to form and to remain as a more or less permanent feature. If insufficient, we should expect a lake to form during part of the year, and in the summer months the standing water would evaporate, leaving a mud flat. Another case might be mentioned, and that is where the ground water plus the rainfall would be insufficient to form standing water and only just sufficient to maintain a mud flat during a part of the year.

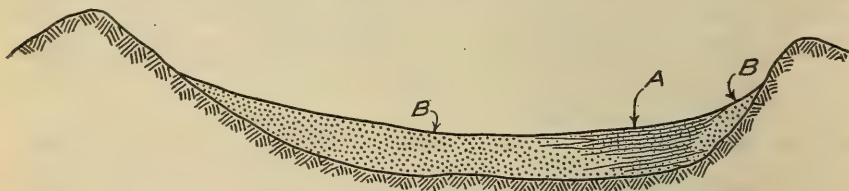


FIG. 5.—Cross section of a basin having higher mountains on one side than on the side opposite.

In the case of figure 4 ground water would be present beneath the entire basin and this would be in some cases artesian water. If the silt portion A maintained its homogeneity ground-water accessions could come only from the marginal portions of the playa area. That this is not an ideal condition may be concluded from the fact that a spring, or springs, is not infrequently found in the central portion of the playa. In some cases this spring is sufficient to supply a small pond and in others the water flows out and evaporates. An excellent example of this kind is found in Rhodes Marsh. In almost the center a spring makes its appearance and a flow of some magnitude runs out and meanders on the flat to be lost by seepage and evaporation. During some years the rainfall plus this flow is sufficient to form a shallow lake.

A conspicuous feature of many of the playas is the marginal rim of mud about the relatively dry central portion. Silver Peak, Rhodes, Death Valley, and Teels Marsh are examples.

Another condition merits mention here. Often a playa will be in the focus of some dominant surface drainage or ground-water drainage. These combined are sufficient

to feed a stream for a portion of the year and the basin receives sufficient water to form a permanent lake. The lakes occupying the Quaternary basins are of this character.

Respecting the movement of salines in solution, it will not be out of place to mention the following: Assuming the ideal basin, and considering such a basin supplied by rainfall and not receiving the discharge of any stream, the run-off ground water reaches the central playa and brings with it more or less soluble salts. The ground water which seeps in from the margins brings in considerable salts. This is shown by the crusts and efflorescences which are continually forming on the marginal portions. The water which comes from springs in the central part of the playa is comparatively free from salts. We would expect that the deeper water would be comparatively free from salines and only in the case where it flowed up through saline beds would we expect to find much evidence of soluble salts. A not unimportant conclusion may be drawn here and that is that artesian flows in the central portion of a playa, if free from more than nominal amounts of soluble salts, indicate the absence of deposits of salt at depth.

PLAYAS.

Desert basins not occupied by perennial lakes may be divided into two groups—mud playas and marshes. The former are playas which are dry and without any great accumulation of underground waters; the marshes are playas noteworthy on account of the accumulation of considerable bodies of underground water and in which the water can be found comparatively close to the surface. For convenience in presentation, I have divided the marshes into two types—marshes in which there is no evidence to show of the existence of a former lake having a level higher than the present surface of the playa, and marshes in which there is evidence of a former lake with surface higher than the present level of the playa. Examples of these are as follows:

Playas.—Most of the smaller desert basins having small drainage area fall into this class. The small playas north of Reno; the Alkali Flat in Gabbs Valley; Sarcobatus Flat, Amargosa region; Big Smoky playa; and the playas near Mina and Luning.

Marshes (first type).—Rhodes, Teels, Silver Peak, Saline Valley, Fish Lake Valley, Death Valley.

Marshes (second type).—Columbus, Panamint, Sand Springs Flat, Searles, Railroad Valley, Black Rock Desert, Dixie Valley, Alvord Marsh.

The list is not complete and it is evident that the line of demarcation is not a sharp one. Changing climatic conditions might be expected to alter the classification.

MUD PLAYAS.

Playas of this type can not be looked upon as the locus of important accumulations of salines. The small drainage area and the arid climatic conditions would result in little accumulation of ground water and that would be at considerable depth, well without the zone of possible concentration by evaporation. For example, the playa just east of Mina, Nev., contains two wells close to the western edge of the silt area. One well shows water at 112 feet and the other at 114 feet. The water from these wells is used for railroad and town purposes. This example is, perhaps, not as good a one to illustrate the point as could be desired on account of the fact that the underground water probably drains into Rhodes Marsh some 6 miles south and 152 feet lower. Ground water may be looked for at varying depths in almost all playas of this type. What salines are present are, however, at the surface, in thin crusts and efflorescences or concentrated within the upper portion of the silt area in much the same way as was described under the subject of the accumulations of salts in soils.

Desiccation products at depth in playas of this type are more than otherwise apt to be of slight thickness and dubious value. While it can not be said that lakes did not occupy the playas under the humid conditions of the Quaternary, still it can be said that such lakes must have been very shallow and their saline content left by evaporation consequently small in amount. The absence of beach lines and their accumulation of gravel about the playa is, in my judgment, sufficient to warrant the assumption that a lake was either not present or was a shallow one of periodic occurrence.

MARSHES.

The conditions which pertain to marshes of the first type can best be described by examples. R. B. Dole¹ examined the Silver Peak Marsh, Nev. From his account I have taken the main facts. The area is due east of Blair, Nev. The marsh is 32 square miles in extent and is in a basin having an area of 550 square miles. Tertiary volcanics and sedimentaries, limestones, slates, and quartzites of Paleozoic age, and

¹ Bul. No. 530R, U. S. Geological Survey.

granite and Quaternary and recent alluvium surround the marsh.¹ The climatic conditions are arid. As a result of the examination of the material obtained from bores placed at a number of points on the marsh, Dole describes the structure in the following words:

"Brown mud 5 to 20 feet deep forms the upper layer of the marsh. Because of the intense heat the surface of this mud is usually baked dry and hard enough to support the weight of teams. Small scattered tracts have become dry enough to be pulverulent for a depth of 1 to 2 feet, but over the greater part of the playa 4-foot holes are sufficiently deep to strike soft mud. As this layer is composed of very small particles and contains a large proportion of clay, the strong salt waters in it circulate very slowly. The mud contains a great quantity of salt, though the crystals are small. The brines obtained from it are very strong, and the surface is generally covered to a depth of one-eighth to one-quarter of an inch by a white crust of salt that has crystallized from solutions drawn to the surface by capillarity.

"The upper mud along the west shore of the playa, particularly west of the 'islands,' contains nodules of calcareous tufa, which apparently have been formed by deposition of calcium carbonate from the hard waters percolating into the marsh from Mineral Ridge. The record of boring No. 13 shows that clay under the mud west of the 'islands' is underlain by white tufaceous materials, but no salt occurs at a depth less than 41 feet except that in the abundant weak brines.

"Well-defined beds of clay containing crystals of gypsum were penetrated east of Goat 'Island' in borings Nos. 3 and 6, and these are underlain by beds of crystallized salt containing saturated brine. Very stiff black, blue, red, gray, and brown clays underlie the beds of salt or mixed salt and clay in boring No. 3 to a depth of 55 feet, but in boring No. 6 the clays are interrupted by a stratum of gypsum-bearing clay below the salt and a 6-inch stratum of salt at 47 feet, below which clay was again encountered.

"Except a shallow bed of light-gray calcareous material at 16 feet nothing but clay containing weak brine was struck to a depth of 40 feet in boring No. 14, at the south end of the playa.

"Borings Nos. 11 and 12 indicate that the beds of salt in the northeastern part of the marsh are denser than those farther south. The mud is underlain by clay and that in turn by crystallized salt so hard that it has to be drilled. A much harder formation, probably calcareous tufa, was struck below the salt in both borings at a depth of about 36 feet.

"The data afforded by the six deeper borings lead to the conclusion that the northeastern two-thirds of the playa is underlain at a depth of about 20 feet by beds of crystallized salt, 5 to 15 feet thick, mixed with more or less clay. It is doubtful if deposits of so great extent occur west of Goat 'Island' or south of Alcatraz 'Island.' Besides these beds practically all other strata to a depth of 50 feet contain appreciable proportions of salt that readily dissolves in water percolating through them."

It is to be regretted that a greater number of borings were not made and the structure of the marsh more accurately determined at greater depths over the northern half of the basin. In a crude way the structure indicates the following cycle of events:

1. The formation of a lake of unknown depth, but with a surface level below the present level of the marsh. Salines accumulated in this lake, and a general silting up took place. The area of this lake could not have extended much over two-thirds of the area of the present marsh.

2. A period of desiccation in which a thin bed of salt was deposited at a depth of about 48 feet below the present surface. Complete desiccation may not have taken place but concentration sufficient to produce a saturated solution and the crystallization of some of the sodium chloride (bore hole No. 6 shows one-half foot of crystals of salt at 47.5 feet depth). Silts and clays were deposited and covered the layer of salt crystals. Increased rainfall prevented further deposition of salt by diluting the lake waters.

3. The silting up of the lake continued to a level within 38 feet of the present surface. Through the latter part of this period desiccation and consequent concentration of the lake water proceeded simultaneously with the silting up.

4. At this time the concentration of the lake was sufficient to precipitate gypsum (bore hole No. 6, 38 feet, shows gray clay containing gypsum crystals). A period of desiccation followed, and a salt bed was gradually built up reaching a position from 29 to 31 feet below the present level and a thickness of 6 to 7 feet. A period of interruption followed, and then further deposition of salt took place, the extent and thickness of the salt bed increasing. This second layer of salt reached a thickness of 6.5 to 7.5 feet, forming, with the lower layer, a bed in the lowest part of the basin

¹ For areal Geology see Professional Paper No. 55, *Ore Deposits of the Silver Peak Quadrangle*, J. E. Spurr.

about 12 feet thick and thinning out on the edges to 6.5 feet. Almost complete desiccation must have marked the end of the period.

5. A greater rainfall changed conditions, and a shallow lake formed. More or less silting and deposition of clay sealed over the salt beds. Desiccation succeeded this comparatively brief interval, and the lake shrunk and deposited a thin layer of salt over a restricted area (2.5 feet of salt in boring No. 12) at a depth of 18 feet from the present surface.

6. A greater rainfall produced a shallow lake, perhaps not more than 10 or 15 feet deep. This lake gradually silted up and slowly evaporated until the present condition was reached.

The lake is dry for perhaps the greater part of the year, and only in the wettest years is water present on the surface. The silting up of the lake must have been accomplished in a large degree by æolian action. The presence of a recent volcanic cone on the western edge of the marsh indicates one of the sources, at least, of the material which filled the lake. The mass of silts and muds filling the lake basin contains a saturated brine.

A chemical examination of the brine indicates the nature of the salines accumulated in this lake bed. From the work previously cited the following table is taken:

Analyses of composite samples of brines—Silver Peak Marsh.¹

[Parts per 100,000.]

Constituent.	1	2	3	4	9	10
Cl.....	59.37	59.01	57.35	60.11	59.16	58.32
SO ₄	.88	1.70	1.30	.99	1.09	1.61
CO ₃	.01	.01	.83	.01	.29	.69
Na.....	36.12	36.54	32.87	34.65	34.38	34.37
K.....	2.71	2.26	5.12	2.95	3.69	3.11
Ca.....	.67	.36	1.92	1.25	.84	1.29
Mg.....	.24	.11	2.49	.04	.48	.50
Fe.....						
Al.....		.01	.12		.07	.11
SiO ₂						
Total solids on evaporation, parts per 100,000.....	100.00	100.00	100.00	100.00	100.00	100.00
	278.76	264.03	48.82	233.44	57.60	39.33

¹ W. B. Van Winkle, analyst. Table recalculated from Bul No. 530R, U. S. Geological Survey.

1. Composite of samples from boring No. 3 at 15.5 feet and from No. 6 at 21 and 40 feet.
2. Composite of samples from boring No. 11 at 27 and 35 feet and from No. 12 at 10, 20, and 27 feet.
3. Composite of samples from boring No. 13 at 16, 31.5, and 40 feet.
4. Composite of samples from boring No. 14 at 11 and 17 feet.
9. Water from boring No. 1 at 6 feet, collected June 1, 1912.
10. Water from boring No. 1 at 27 feet, collected June 4, 1912.

The order of the ions is:

Na.....	35.14	Cl.....	58.86
K.....	2.94	SO ₄	1.26
Ca.....	1.05	CO ₃	.30
Mg.....	.64	SiO ₂	.06

Carbonates and sulphates are inconspicuous in amount. The brines consist almost wholly of sodium and potassium chlorides. They are practically saturated. The ratio of sodium to potassium is 11.9. The brines at depth show a somewhat smaller content of potassium than the composite samples. The average is 0.69 per cent of the total solids.¹ Dole gives the analyses of four spring waters tributary to the basin; two are from hot springs and two from cold. These waters have a chemical content very much the same as the brines. They are slightly higher in sulphate radical and average slightly higher in potash content. The sodium-potassium ratio is 10.8.

Certain interesting observations were made upon the brines. In boring No. 12 the brine encountered at 8.5 to 10 feet rose to 1.8 feet (head of 7.45 feet); those at 18 to 20.5 feet rose to 7.5 feet (head of 11.75 feet); those at 22 to 35 feet rose to 8 feet (head of 20.5 feet). A similar condition was noted in bore No. 11 and most of the other bores which penetrated the brine body. These observations indicate the effect of pressure no doubt caused by the elevation of the water plane in the ground water outside the main silt area.

The source of the salines has been discussed by Spurr.² He reaches the conclusion that the weak brines discharged by springs around the marsh are the source. Dole

¹ Bul. No. 530R, U. S. Geological Survey, p. 14.

² Professional Paper No. 55, U. S. Geological Survey.

suggests that these springs may derive their salines from the marsh itself. Both Dole and Spurr state that the leaching of the Tertiary stratified rocks which are present in the basin in extensive areas accounts for much of the saline residue. If Dole's estimate of the quantity of salt, 15,000,000 tons, be taken, and the area of the basin considered, 1.9 pounds per square foot of the basin surface would account for this quantity. It would not be unreasonable to expect this to be derived from the erosion of the Tertiary sedimentaries and volcanics, especially when we consider the great amount of erosion which has taken place in Clayton Valley. Spurr points out, however, the conspicuous absence of borates in the salines of the Silver Peak Marsh and their presence in the neighboring playa to the west—Fish Lake Valley. In both localities Tertiary sediments are common. He rightly reasons that if these sedimentaries were responsible for the salines, borates would also be present in the Silver Peak salines. His conclusion that the salines of the Silver Peak Marsh are derived from hot springs at the edge of the playa would not account for the absence of borates at depth. Three possible hypotheses suggest themselves: The absence of the "borate member" in the Tertiary sedimentaries of the Silver Peak Basin and its presence in the Tertiary sedimentaries tributary to Fish Lake Valley; deeper borings in the Silver Peak Marsh might reveal borates; the volcanic activity in the Silver Peak Marsh was not characterized by emanations of boric compounds.

The source of the borate compounds in Tertiary sedimentaries is generally conceded to be due to contemporaneous vulcanism. This must have been local and would result in localization of boraciferous strata in the Tertiary series. This leads me to favor the first hypothesis. I do not, however, consider the question settled, and further data must be obtained before it can be.

I am inclined to the view that the major part of the salines were derived from the erosion of the rocks of the basin; that possibly recent volcanic activity was responsible for a part also; and that much of the present surface accumulation is due to the springs and seepage water.

Dole estimates the quantity of salt in the Silver Peak Marsh as 15,000,000 tons within the first 40 feet. The deposit has commercial possibilities for the production of salt. The average of the analyses upon the four brine composites shows 2.76 per cent potassium in the anhydrous residue. This is equivalent to 5.2 per cent potassium chloride. It is doubtful whether this is high enough to warrant the attempt to separate the potassium salt. The association of the brine with compact muds would prevent it from freely flowing to a bore hole. There would be, therefore, some difficulty in obtaining sufficient brine from a few bore holes to supply evaporating vats. The small amount of carbonate and sulphate would render the problem of the separation of the sodium and potassium chlorides comparatively simple. The production of sodium chloride with a by-product rich in potassium chloride is not beyond the possibilities of commercial exploitation.

Conditions in Rhodes, Teels (Pl. I, fig. 1), Fish Lake Valley, and Saline Valley are very much the same as in Silver Peak Marsh. Undoubtedly shallow lakes occupied each of these basins, and the filling-in process and the desiccation of the lakes must have been similar. Unfortunately the results of systematic boring are not obtainable. No doubt each of these presents individual characteristics and differs in some details from the example described. The most marked difference is in the presence of borates.

In Fish Lake Valley, Turner states that there are four playa deposits, all of which have been worked for borax. Analyses by G. Steiger show in one case chloride, sulphate, carbonate, and borate of sodium. In another, sulphates and borates of calcium and sodium. No mention is made of potassium in the analyses.¹

The conditions at Rhodes Marsh have been described by LeConte.² His observations are summarized below.

The central area is occupied by a salt crust consisting of almost pure sodium chloride. About the salt area and below the surface soil is a comparatively thick bed of sodium sulphate. Sodium carbonate occurs in soft crusts 2 or 3 inches thick, but is not general. Borax and ulexite also occur. The ulexite is in the form of nodules imbedded in wet, stiff clay in the semicircular area surrounding the central salt area on the north, northwest, and northeast. The borax occurs on the west, southwest, and southeast of the central salt area. It is in a moist, stiff clay which is full of the transparent crystals. It also occurs as a crust from 1 to 3 inches thick. This crust renews itself. The localization of the salts is attributed to the action of springs, and the concentration of the pure sodium chloride in the lowest part of the playa is attributed to the leaching of this compound by surface waters. It is evident from the description that the salines in the marsh are much more complex than those in the Silver Peak area. The regional rocks are similar to those about Silver Peak. The playa is of special interest in that

¹ Professional Paper No. 55, U. S. Geol. Survey, pp. 158, 159, Spurr.

² Third Annual Report State Mineralogist of California, 1883.

it more nearly approximates the ideal type described before than any other. It is a circular basin of 232 square miles area, occupied by a playa of 3.2 square miles area. The ratio of basin area to playa area is 72.5. It receives its principal underground waters from the Sodaville-Mina Valley. Undoubtedly its history is similar to the Silver Peak Marsh. The central area is occupied by a reddish-brown mud, locally covered by efflorescences. In places the mud is dried to a brown, pulverulent soil, containing more or less sodium chloride and small amounts of other salines. The present movement of the salines from the deeper beds is taking place, first, by slow upward movement of the water contained in the muds (caused by capillarity), and, second, in the marginal portions by a slow movement upward caused by capillarity and by the banking up of the water plane where it strikes the more or less impervious mud bodies of the central playa. The water of the central area is saturated with salines and deposits them as crusts at the surface. In the marginal portions the underground water becomes more or less saturated as it passes through the beds and carries saline material to the surface, where it crystallizes out. LeConte's idea in a large measure is correct. His term "springs" would include seepage water in all its phases of upward movement. Occasional heavy rainfalls produce sufficient run-off to form a shallow lake. Such waters dissolve salines and concentrate them in the central depression. Salt is the principal compound concentrated in this manner.

A number of analyses were made upon samples of salines from this marsh, but potassium in small amounts only was found. A sample of moist sand and salt from the central part of the playa shows the following:

Analysis of salt in sand from playa, Sample No. 15.

[Analysis by J. A. Cullen.]

	Per cent.		Per cent.
Ca.....	1.20	SO ₄	47.68
Mg.....	.44	Cl.....	14.17
K.....	3.03	CO ₃	3.09
Na.....	30.39	Total soluble salts in sand	12.15

The analysis shows sodium sulphate and chloride in greatest amount. Minor amounts of sodium carbonates and some potassium chloride are shown. The sodium-potassium ratio is 10. No analyses of the brines are available. Excepting for the borax and salt, this marsh is a very doubtful source of commercial salines. The potash content is too low and its separation would be complicated by the presence of sulphates and carbonates.

SALINE VALLEY, INYO COUNTY, CAL.

This is an inclosed basin. The central portion, of about 12,000 acres extent, is covered by a salt crust 2 inches thick and beneath are muds saturated with brines. When the crust is scraped off it renews itself in about 15 days. At almost any place over the salt area at a depth of 2 feet salt brine can be obtained. In warm weather the salt crystallizing out is pure; in cold, it contains small amounts of soda. The salt deposits are being worked and preparations are being made on a large scale for its shipment by the Saline Valley Salt Co. The regional rocks about this basin are granites, limestones, and volcanics. Marsh borax was worked at one time in the valley.

A single sample of the salt crust from this valley was submitted and found to contain 40.98 per cent soluble salts, and the soluble salts contained 4.2 per cent potassium. Three brines and one spring water were also submitted. The analyses follow:

Analyses of brines and spring water from Saline Valley.

[Per cent of total solids.]

No.	Ca.	Mg.	Na.	K.	CO ₃ .	HCO ₃ .	Cl.	SO ₄ .	Total solids on evaporation, parts per 100,000.
1.....	10.0	3.08	13.84	Tr.	Tr.	7.64	24.62	28.46	130
2.....	1.18	.37	36.31	1.17	.07	.03	48.78	12.85	35,506
3.....	1.55	.79	34.38	.73	Tr.	.15	48.70	13.37	8,237
4.....	2.97	.73	32.57	.71	Tr.	.28	45.45	17.30	4,238

No. 1. Spring water.

No. 2. Brine from center of flat.

No. 3. Brine from pothole on south edge of flat.

No. 4. Brine from pothole one-half mile east of No. 3.

Analyses by J. A. Cullen, Bureau of Soils.

Sufficient data are not available properly to characterize this area. It is not unlike the Silver Peak Marsh. The potassium content of No. 2 brine, the highest, is less than for the average of the Silver Peak brines. The high content in the single sample of the crust material is not considered significant, since samples of this material occasionally run high in potassium.

DEATH VALLEY.

Death Valley receives the drainage of the Amargosa River. The drainage area is given as 23,160 square miles by Free's table of basin areas. The area of the playa is approximately 160 square miles, not including Mesquite Valley in the northern end. The ratio of basin to playa is 144 to 1.

The valley lies between the Panamint Range on the west and the Amargosa Range on the east. It has a length of 120 miles and a width varying from 3 to 10 miles. Much of the valley area lies below the sea level. The lowest point on the topographic sheet is -280 feet. Ball states that some 15 miles farther south from this point the depression is 125 feet deeper. The Panamint Range reaches its maximum elevation at Telescope Peak, 11,045 feet, an air-line distance of about 12 miles from the -200-foot contour of Death Valley. The Amargosa Range reaches an elevation of 6,397 feet at Funeral Peak, a distance of 6 miles from the -200-foot contour; 6,725 feet at Pyramid Peak, a distance of about 12 miles from the -200-foot contour; and 5,420 feet at Chloride Cliff Peak, a distance of 10 miles from the -200-foot contour in Death Valley. The Panamint Range averages from 7,000 to 9,000 feet altitude and the Amargosa from 6,000 to 7,000 feet. The maximum grade on the west from Telescope Peak to the valley is 920 feet per mile (9.8°), and on the east, measured from Funeral Peak, 1,066 feet per mile (11.4°). The canyons leading to the valley do not approximate these grades, except in their upper ends, but the average grade is very steep. In consequence of these steep grades and the torrential character of the occasional rain storms, alluvial fans and mountain aprons have been developed on a vast scale. The narrowness of the valley has resulted in the development of a structure similar to that shown in figure 4. Undoubtedly many of the fans overlap beneath the central basin.

The floor of the valley is level, but on the flanks are low hills, some of Tertiary sediments (Pl. I, fig. 2), and some of alluvial material representing the residual portions of alluvial fans attacked by recent erosion. Mesquite Flat, in the northern end of the valley, is covered with sand dunes. There are no positive evidences of a lake during Quaternary times. Some evidences of a shallow, recent lake in the area east of Bennetts Wells are discernible in faint shore lines, which indicate a depth of 6 to 12 feet.

An enormous deposit of salt occupies the lowest depression. The salt area begins south of Salt Creek, 6 miles northwest of United States land monument No. 34, and extends to a point south of Mesquite Spring. The length of the salt area is from 30 to 32 miles, and its width ranges from 2 to 4 miles. Over a large part of this area the salt appears as a crust composed of pinnacles and fantastic, twisted masses. (Pl. II, fig. 1.) It is said that some of the rough salt pinnacles reach a height of 6 feet. The average height of those I saw would be from $1\frac{1}{2}$ to 2 feet. The thickness of the rough salt varies. Campbell¹ states that it can not be less than 1 foot thick. Free states that the thickness of the upper crusts is 18 inches. Below this is 3 feet of mud, then 18 inches of salt, and then mud to 10 feet at the place where he tested.

In the so-called sink east of Bennetts Wells and about 18 miles south of Furnace Creek Ranch is an area of smooth salt. (Pl. II, fig. 2.) On the eastern edge of the valley this is separated by a narrow rim of mud and rough salt from the alluvial wash of the Amargosa Range. On the north the area is bounded by rough salt which extends across the floor of the valley. The first foot of the smooth salt area is composed of layers of crystalline salt 2 or 3 inches thick, separated by thin seams of mud and sand. Brine comes to within a fraction of an inch of the surface. A slight scraping of the surface is followed by the flowing in of the brine. The surface of the salt is divided into small polygonal areas by thin cracks through which the underlying brine has been drawn and in crystallizing has left low welts of crystallized salt cementing the cracks together. As far as I have been able to ascertain, no measurements of the thickness of this salt have been made. B. K. Brockington estimates that the total area of incrustation is approximately 150 square miles. Of this about one-third, or 50 square miles, is smooth salt, the greater part of this being in the sink east of Bennetts Wells.

In the rough salt area, holes show a brine to be within 1 or 2 feet of the surface. Within this area also occur potholes, circular openings from 2 to 4 feet in diameter

¹ Bul. No. 200, U. S. Geol. Survey, p. 18.

and of varying depth and filled with brine. (Pl. III, fig. 1.) The interior of the holes is lined with salt crystals. About the edges, surface tension has drawn the brine up and the margin of the hole is crusted with efflorescences of salt. Near the "land" edge of the rough salt area many holes are to be seen, some more or less arched over by salt crusts and dry mud, and always containing water. Areas of soft red mud also occur between the rough crusts and the outer margin. These are often difficult and dangerous to cross. The formation of the rough salt crusts may often be seen upon these mud areas. The explanation appears to be as follows: The surface mud dries, forming cracks, and in shrinking leaves narrow channels, bottomed by soft mud, between the cracks. Through these channels the brine solution slowly passes up and crystallizes, forming veins of salt. As the mud cakes dry, they curl upward on the edges, opening the channels wider and allowing more brine to work upward. This crystallizes in part and in part is drawn by surface tension over the surface already crystallized, forming thicker crusts. The brine in the soft mud below is steadily supplied, and the crusts build up until they practically seal the brine over. More or less evaporation must continue beneath the crusts, and as the salt crystals form they must crowd the mud and crusts up, forming the characteristic windrows of mud and salt on the marginal portions. The slow consolidation of the mud, as well as the banking up of the ground water on the periphery against the mud mass, would account for the upward movement of the brines. Rain water would dissolve the salt from the crusts thus formed, and it would collect in small puddles between the roughened masses, where it would be evaporated to a brine. Surface tension would draw this brine up upon the rough masses of salt and, evaporating there, would thicken and build up the irregularities of the salt. The evaporation of a salt solution in a beaker and the climbing of the salt up the sides is a familiar laboratory phenomenon.

The smooth area of salt is built up by fresh accessions of brine coming from the action of rain water upon the neighboring rough salt areas. Shallow channels (sloughs) meander through the rough salt and collect part of the brine formed by the occasional rains, discharging it upon the smooth salt, where it is speedily evaporated. Wind-blown material collects in the thin sheets of brine and mingles with the salt crystals. The general admixture of soil impurities in the rough salt is also explained in this way. It is evident that the smooth salt area would eventually reach a level that would permit little or no drainage to collect, and the salt bed would no longer be built up. Slow consolidation of the silts and clays in the lowest depressions would extend the differentiation of level over a long period. Differential consolidation would be expected in an area like Death Valley. The finest clays and silts in the lowest depression or sink would consolidate at a greater rate than the sand and alluvial material forming the greater part of the Death Valley filling. The consolidation of the clays and muds would be expected to force the solution upward and even outward. The brines forced outward would be diluted by mingling with the underground waters coming from the neighboring watersheds. We would expect the marginal water to be lower in saline content than that in the smooth salt area, and samples and analyses show this to be the case. Reference is made to the results of samples Nos. 339, 341, and 342. The sample No. 339 was taken on the west side of the valley, due west of Furnace Creek Ranch; No. 341 was taken one-fourth mile east of No. 339, and No. 342 one-quarter mile east of No. 341. They show, respectively, 2.77, 15.12, and 34.18 grams total solids per 100 cubic centimeters.

Campbell states that Death Valley is one of the best watered areas within the Amargosa region and that the water is, for the most part, good. An inspection of the topographic sheet shows many of the water holes to be close to the edge of the central playa. At Bennett's wells the water is within $1\frac{1}{2}$ feet of the surface. Most of the wells are shallow. The explanation of this has been given under the structural development of a playa.

CHEMICAL DATA FOR DEATH VALLEY.

Four sets of analyses are given in Tables XXI, XXII, XXIII, and XXIV (Appendix). The composition of the brines in Table XXI gives perhaps the best conception of the character of the salines present in Death Valley. The average percentage of ions based upon the percentage of total solids in the order of their magnitude is Na, 36.12; K, 2.63; Mg, 0.3; Ca, 0.2; Cl, 53.7; SO_4 , 5.62; CO_3 , 0.18. Sodium and chlorine are the dominating ions. Carbonates are insignificant in amount. The sulphates are in greater amount than in the Silver Peak brines. Potassium is in smaller amount than the Silver Peak brines. The sodium-potassium ratio is 13.7; in the Silver Peak brines it is 11.9. These ratios indicate parallel conditions in both places. Calcium and magnesium are insignificant in amount. It should be noted that there is comparative agreement between the results obtained upon samples taken by different persons.

B. K. Brockington submitted several brines to the Cooperative Laboratory from this locality, and the results upon these closely corroborate the samples taken by Free and Jones.

It should be noted also that borate compounds are found in Death Valley; just north of Bennett's Wells is the Eagle Borax Works, now abandoned. Surface crusts were gathered at this place and refined. North of Furnace Creek Ranch is an old borax mill. The playa in the vicinity was the source of the borate minerals. This deposit is practically at the mouth of Furnace Creek. The well-known deposits of colemanite in Furnace Creek Canyon were undoubtedly the source from which the marsh borax in the valley came.

The borax deposits in Death Valley are no longer worked. No salt has been produced on account of difficulty of access and climatic conditions. The potassium content of the brine is probably too low to warrant attempts at separation. Until deeper borings are made in the smooth salt area and the composition of the brines at depth determined, Death Valley must still be looked upon as a possible source of potassium salts. It is, however, a matter of reasonable doubt whether a greater content of potassium will be found at depth. Death Valley is of interest in that it indicates a transition stage in the formation of a saline deposit at depth. It would not take a very great increase in rainfall to bring down debris sufficient to cover and seal the present salt deposit.

Since the foregoing was written the results of borings and analyses upon the brines obtained therefrom by the United States Geological Survey became available and are given below.

Log of United States Geological Survey boring No. 3, Death Valley, Cal.

Salt (1½ inches thick on surface).	Feet.
Mud, light brown, containing coarse salt crystals.....	1.5
Salt layer 2 inches thick with flow of brine at bottom.	
Mud, soft brown.....	29.0
(Small flow of warm water at depth of 30 feet.)	
Mud, yielding seepage of water.....	2.5
Clay or mud and crystals of salt.....	1.5
Salt.....	.5
Mud, black, and crystals of salt.....	1.5
Salt.....	.5
Mud, black, and crystals of salt.....	15.0
(Water all shut off and auger cut without seepage.)	
Salt.....	.3
Clay, black, with occasional thin salt layers.....	3.7
Salt, crystalline, hard, containing layers of black clay mixed with salt crystals 1 to 4 inches in thickness at intervals of about 2 feet.....	8.5
Mud.....	.5
Salt, crystalline, apparently solid.....	13.0
Mud.....	2.2
Salt, crystalline.....	3.8
Clay, black.....	1.0
Salt, crystalline.....	2.0
Clay, black, containing salt crystals.....	10.5
(No water encountered in the lower part of the well.)	
Total.....	96.0

Analyses of potash in natural brines from Death Valley, Cal.

[W. B. Hicks and R. K. Bailey, analysts.]

Description of sample.	Depth in feet at which sample was taken.	Total salts (ignited residue) expressed as percentage of original solution.	Potash (K_2O) expressed as percentage of ignited residue.	KCl expressed as percentage of original solution.
Ground water in the salt crust at the "sink".....	0.5	28.19	3.43	1.53
Water in open "pothole".....	.5	27.47	1.20	.52
Do.....	9.5	27.48	1.18	.51
U. S. Geol. Survey well No. 1.....	6	27.87	2.85	1.27
Do.....	24	28.64	2.22	1.01
Do.....	29	28.96	2.35	1.09
Do.....	52	28.66	2.01	.91
U. S. Geol. Survey well No. 2.....	32	28.33	1.54	.69
Do.....	38	29.16	1.78	.82
Do.....	70	29.96	2.48	1.18
U. S. Geol. Survey well No. 3.....	1	27.78	2.05	.90
Do.....	30	27.91	1.68	.74
U. S. Geol. Survey well No. 4.....	32	28.77	2.23	1.02
Do.....	38	28.73	2.12	.97
Average.....		28.42	2.08	.94

Gale comments upon these results as follows:

"No shore markings or other evidence of former deep submergence of Death Valley have yet been discovered. It appears that the deposits laid down in this valley have been chiefly the results of temporary shallow submergences and alternate desiccations. Thus the deposits that make up the floor of this valley are supposed to have been built up layer by layer, the salts having crystallized from the water evaporated from the temporary shallow lakes and having been occasionally buried in mixtures of sand and silt, including more or less saline material swept in by occasional floods. This is the process that is going on at the present day.

"A vast amount of saline material is accumulated in the bottom of this valley, but the mode of its deposition probably is not favorable to selective crystallization on a large scale. Segregation of potash or any other portion of the soluble constituents of the waters may have taken place to slight extent in the individual salt crust layers, but under the conditions described any such differentiation is likely to have been restricted to the individual layers as units, and therefore has occurred on a scale so small as to be of doubtful practical importance. It seems evident that unless a vast body of saline material has been deposited at one time during a single period of desiccation that there would be little chance for the various dissolved constituents to become segregated one from another on a large scale. There is no record of the drying up of a single large lake of saline waters in Death Valley. Although it is possible that the shores of such a lake might have been completely buried, the assumption that this may have happened must be purely a matter of speculation."

The potassium content of the saline residues from the brines obtained from the United States Geological Survey bores is lower than the average for the brines obtained from the surface potholes, the figures being, respectively, 1.73 and 2.63 per cent. There is practical agreement in the results since some concentration of the potassium salts might well be looked for in the surface brines.

While the results of the Survey's work in Death Valley are disappointing, they are of considerable importance, as they give much information concerning deposits of this character. The conditions at depths greater than 100 feet are unknown, but it is fair to presume that they are not unlike those within the first 100 feet. Salines in vast quantity have collected in Death Valley, but concentration of the most valuable salines has not taken place on anything more than a very local scale. For the concentration of these salines extreme conditions of aridity must be looked upon as unfavorable. A deep lake, existing for some considerable time and then quickly drying up, appears to be the condition necessary for the concentration of the most soluble salines.

MARSHES OF THE SECOND TYPE.

Marshes of the second type have a special interest in that the presence of a former lake indicates a much greater run-off, and consequently a greater amount of saline accumulations. The desiccation of such a lake would be more apt to produce work-

able beds of salines than marshes of the first type. Descriptions of Searles and Columbus Marshes, Railroad and Dixie Valleys, Sand Springs Flat, and Sevier Lake follow.

SEARLES MARSH.

Searles Marsh lies in the northwestern part of San Bernardino County, Cal., about 30 miles northeast of Randsburg. It lies in a drainage basin of 4,850 square miles area. C. E. Dolbear states that the area of the central depression is about 62.5 square miles. This would give a ratio of 77.6 square miles of basin area to 1 square mile of central depression area. The lowest part of the depression is 12 square miles in area, and is occupied by a smooth, hard floor of salt (Pl. III, fig. 2). Portions of the area are covered by debris; other portions by efflorescences and crusts from a fraction of an inch to several feet in thickness; and other portions are covered with clay muds which are in part dried out and firm and in part are soft. Plate IV, figure 1, shows a trona reef in the northeastern part of the marsh. De Groot¹ reports results of a boring and shows a section of the marsh. Dolbear² quotes the results of two bores, one in the central salt area and the other in the marginal area outside of the salt bed.

Section of Searles Marsh (De Groot).

- Depth.
 2 feet.....Salt and thenardite.
 4 feet.....Clay and volcanic sand with some hanksite.
 8 feet.....Volcanic sand and black clay with bunches of trona.
 8 feet.....Volcanic sand containing glauberite, thenardite, and a few crystals of hanksite.
 20 feet.....Mud smelling of hydrogen sulphide and containing layers of glauberite, soda, and hanksite.
 28 feet.....Solid trona overlain by a thin layer of very hard material.
 230+feet.....Clay, mixed with volcanic sand and permeated with hydrogen sulphide.

Analyses of samples from borings in Searles Lake.

[Analyses by Dolbear.]

Depth.	Insol.	NaCl.	Na ₂ SO ₄ .	Na ₂ CO ₃ .	NaHCO ₃ .	Na ₂ B ₄ O ₇ .	H ₂ O.
<i>Feet.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
0-18	0.2	79.7	7.6	3.2	0.0	Tr.	3.3
18-25	1.4	44.0	30.5	14.8	2.5	1.0	5.8
25-30	1.4	47.3	28.1	10.6	.0	2.0	10.6
30-35	3.0	42.7	17.1	19.1	5.9	2.0	10.2
35-50	1.4	43.5	22.3	9.5	2.5	5.5	15.3
50-65	Tr.	82.8	10.6	3.2	.8	Tr.	2.6
65-79	Tr.	19.0	7.3	40.3	18.5	.5	14.4

Analyses of samples from borings outside of salt-bed area.

[Analyses by Dolbear.]

Depth.	Insol.	NaCl.	Na ₂ SO ₄ .	Na ₂ CO ₃ .	NaHCO ₃ .	Na ₂ B ₄ O ₇ .	H ₂ O.
<i>Feet.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
0-13	Mud.						
13-20	8.3	66.8	1.0	11.7	5.0	0.4	6.8
20-25	Tr.	98.4	.8	1.8	.0	.0	.0
25-30	1.4	15.3	4.7	38.7	24.4	Tr.	15.5
30-35	15.0	39.6	2.3	16.4	3.4	5.56	12.74
35-40	33.4	17.5	3.9	14.85	4.7	5.6	20.05
40-45	36.0	9.8	2.9	12.5	.4	6.57	26.28
45-50	32.5	9.0	2.6	21.2	3.8	.0	30.9
50-53	30.7	8.3	2.8	23.3	7.6	Tr.	27.8
53-55	31.0	9.0	2.8	21.2	10.9	.0	25.1
55-60	26.9	5.8	1.9	26.5	14.3	Tr.	24.6
60-65	3.2	4.5	38.0	28.6	10.1	Tr.	10.6
65-70	6.8	5.1	6.8	43.5	21.0	Tr.	16.8
70-75	7.6	4.0	2.8	53.0	16.0	.0	16.6

¹ 10th Annual Report, California State Mining Bureau, p. 535.

² Engineering and Mining Journal, Feb. 1, 1913, p. 260.

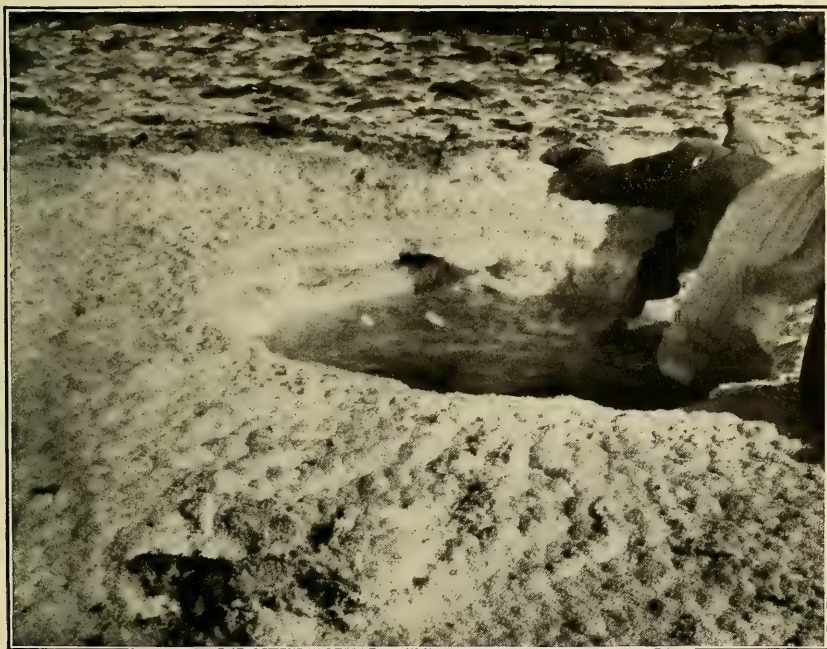


FIG. 1.—POT HOLE, DEATH VALLEY—EAST SIDE; EAST OF BENNETTS WELLS.



FIG. 2.—SEARLES MARSH, CAL. MAIN SALINE DEPOSIT.



FIG. 1.—SEARLES MARSH, CAL. TRONA REEF IN NORTHEAST CORNER.



FIG. 2.—RAILROAD VALLEY, NEV. SALT PAN AT NORTH END.

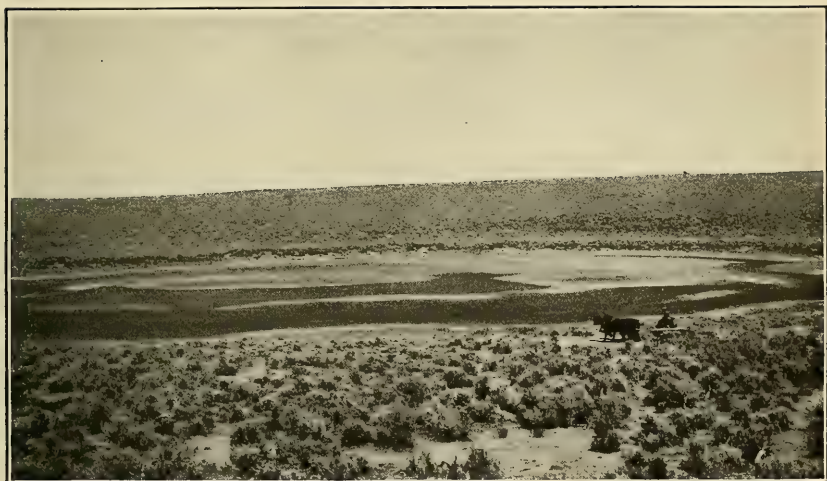


FIG. 1.—LAVA PLATEAU WEST OF ALKALI LAKE, OREG. SMALL INCLOSED PAN.

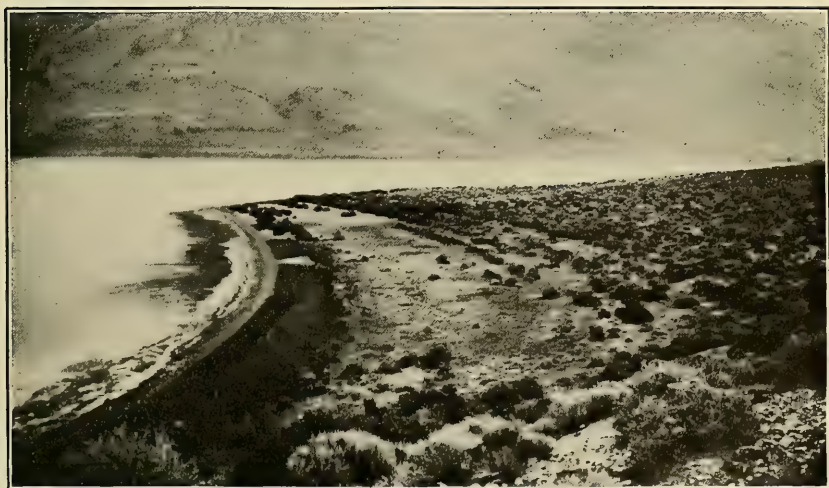
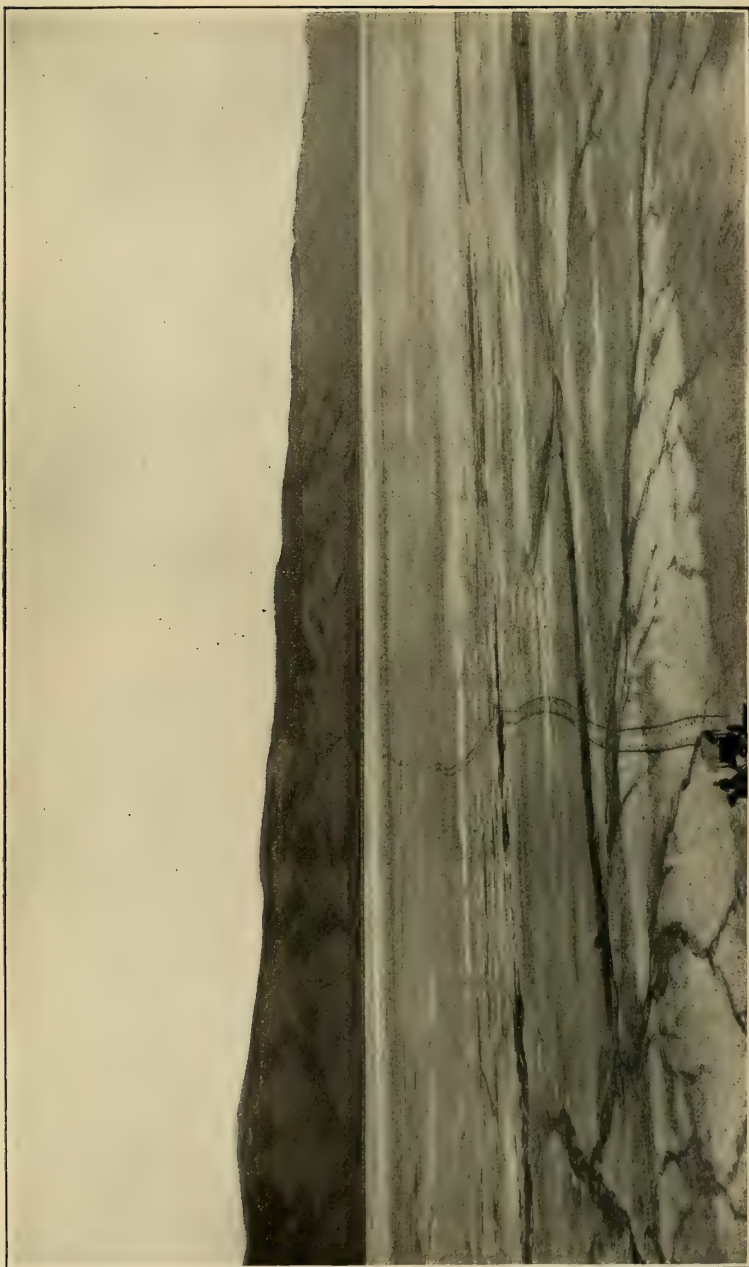


FIG. 2.—ABERT LAKE, OREG. SHORE AT SOUTHEAST CORNER.



SURPRISE VALLEY, OREG. PLAYA OF UPPER LAKE.

Through the kindness of Dennis Searles, E. E. Free obtained the samples from a bore put down over 600 feet in the area northwest of the central salt area and near the road leading from the plant of the California Trona Co. southeast of the salt area. The exact location of this deep bore is not known. The series of samples is not complete, and the notes accompanying them are also somewhat incomplete. The results of analyses upon these samples are given in the accompanying tables. Table XXV (Appendix) gives the total sodium and potassium, soluble sodium and potassium, and insoluble sodium and potassium. Table XXVI (Appendix) gives the ratios of soluble sodium to potassium, of insoluble sodium to potassium, and of total sodium to potassium. Tables XXVII (Appendix) and XXVIII (Appendix) show respectively the percentage composition of the samples, and of the water-soluble material contained in the samples. Accompanying is a brief description of a petrographic study (Table XXX, Appendix) upon the samples of the deep bore by J. C. Jones. It is unfortunate that the record is incomplete, but incomplete as it is, the results of our examinations are of sufficient interest to warrant presentation.

Before discussing the foregoing data, it is necessary to establish certain criteria by which we may determine the nature of the events which took place during the history of this lake.

The progressive or fractional crystallization of brines and salt solutions has been thoroughly discussed by Turrentine.¹ On account of the similarity of conditions, I have deemed it best to take the results which T. M. Chatard obtained in his experiments upon the waters of Owens and Mono Lakes. These results are shown graphically in figure 6.² The waters from both lakes are similar in composition. Mono Lake water has a slightly higher percentage of sodium sulphate than Owens. The water in both cases contains carbonates, bicarbonates, sulphates, chlorides, and borates; also sodium, potassium, and minor amounts of silica, calcium, magnesium, alumina, and ferric oxide. The temperature conditions in the evaporations range from 18.3° C. to 37.8° C. The two sets of experiments indicate similar results. The following are the criteria from these experiments:

1. At initial stages of evaporation calcium carbonate, mixed with more or less ferric oxide, would be precipitated.
2. Saturation would be indicated by a crystalline deposit in which carbonates would predominate. Sulphates would be least and chlorides would be present in moderate amount only. Potassium chloride would be less than 1 per cent of the saline deposit. The ratio between sodium carbonate and bicarbonate in the deposited salines would approach unity.
3. Succeeding stages would be marked by decreasing amounts of carbonates and increasing amounts of sulphates and chlorides. The ratio between sodium carbonate and bicarbonate would rapidly increase. At an intermediate stage sulphates would reach a maximum. Sodium chloride would remain in about the same proportion, or would be slightly increased.
4. Approach to final desiccation would be indicated by the separation of a large proportion of sodium chloride and a small increase in the proportion of potassium chloride.
5. Final desiccation would yield relatively small amounts of sulphates and a larger proportion of chlorides and carbonates. Some borates would be present. The sodium-carbonate and bicarbonate ratio would reach a maximum value, and relatively large proportions of potassium salts would characterize this state.

Four terms may be designated to indicate the progressive stages, and in their natural order are:

- (1) The trona period—sodium carbonate and bicarbonate in about equal amounts preponderate;
- (2) The sulphate period—separation of sodium sulphate;
- (3) The sodium chloride period—maximum proportions of sodium chloride;
- (4) The complete desiccation period—maximum percentage of potassium chloride and presence of borates.

In the case of the uninterrupted desiccation of a saline lake the successive stages mentioned above would grade insensibly one into the other. The actual case would be further complicated by temperature variations, seasonal and periodical, by interruptions caused by the dilution of lake waters, by rainfall and stream discharge, and by silt, mud, and æolian deposition. Wind and wave action would tend to thicken the shore deposits. The thinning out of the lake waters at the margin would set up there more favorable conditions for crystallization than in the deeper portions. In

¹ The Occurrence of Potassium Salts in the Salines of the United States. Bul. No. 94, Bureau of Soils, U. S. Dept. of Agr.

² Data for this figure were taken from Bul. No. 60, U. S. Geol. Survey, pp. 59-65.

the marginal portions silt deposits would be greatest, and the salines deposited here would be characterized by a large proportion of insoluble material. In a single large basin the lake during evaporation might be divided into several smaller lakes, and each would have its individual conditions and in each case would form saline deposits differing from the others. Lastly, the nature of the salines would be expected to differ in different lake basins. The proportions between chlorides, sulphates, carbonates,

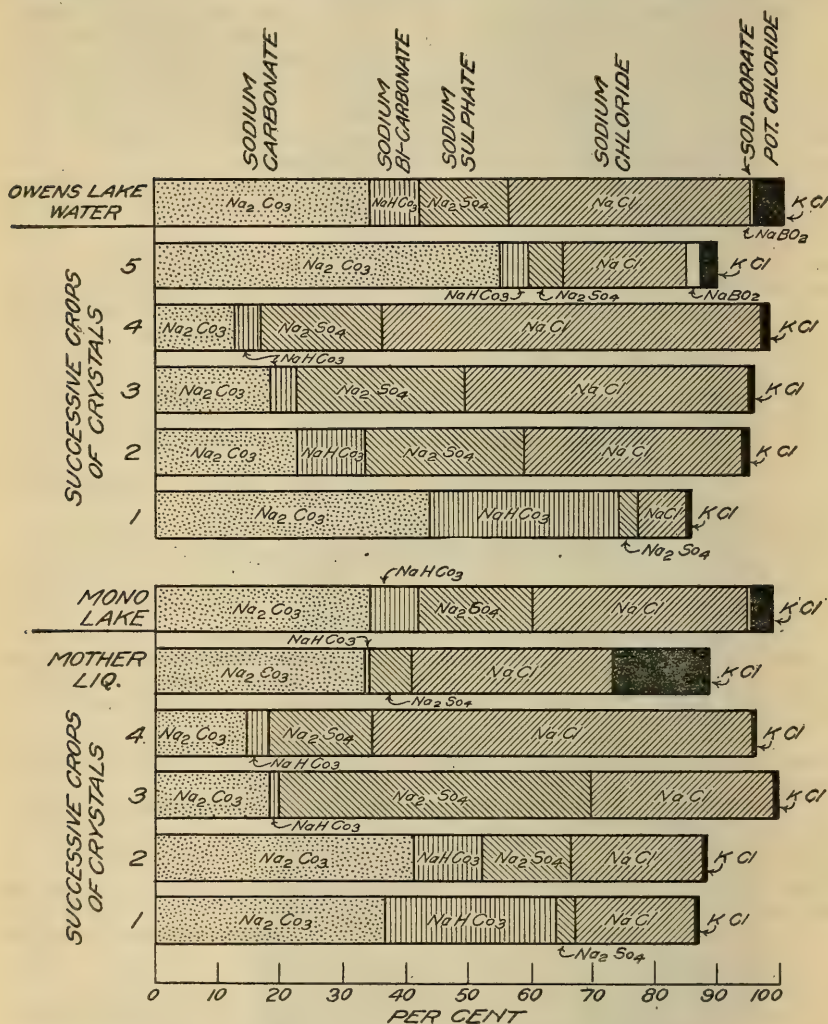


FIG. 6.—Order of deposition of salts in Owens Lake and Mono Lake.

bicarbonates, and the basic ions present would vary somewhat from the two samples chosen for establishing our criteria.

Another condition requires discussion. Salines are deposited upon and in lake bottoms. The lake sediments would include saline waters and, as desiccation proceeded, the lake sediments would include waters containing gradually increasing amounts of saline material. When saturation is reached not only would brine be expected but individual crystals of the different salts would also be so included. If crystallization proceeded faster than sedimentation, the lake sediments would contain larger and larger proportions of saline material. If sedimentation proceeded faster than crystallization, smaller proportions of saline material would be expected. It is evident

that crystallization must proceed at a comparatively slow rate under natural conditions at the beginning of desiccation, and, as desiccation proceeds, the rate of crystallization must increase to a maximum. Final desiccation of the mother liquors must be a long drawn-out process, if at all completed. It is not impossible to expect that at this stage of desiccation sedimentation by æolian action might proceed rapidly enough to absorb the final mother liquor. The crystalline mass formed during the final stages of desiccation would also absorb portions of the mother liquor at the end.

The saline content of a mud, assuming that it has absorbed a brine which is saturated and at point of crystallization, has been calculated in the following: A wet mud with a specific gravity of 2 and composed of mineral particles 2.6 would have a void space of 37.4 per cent by volume. If 1 cubic foot were filled with a brine of specific gravity 1.25, the brine would weigh 29.3 pounds. Chatard's experiments on the Owens Lake water showed a brine of 1.26 specific gravity at incipient crystallization; and this contained 30.56 per cent by weight of salines. The brine filling 1 cubic foot of the mud would contain approximately 9 pounds of salines. This would be equivalent to 8.1 per cent of the weight of the dry mud.¹ Dry mud samples containing an excess of 8.1 per cent of saline material would indicate saturated solution conditions with some crystallization and deposits of salines; less than 8 per cent it would be concluded that the mud had captured an unsaturated brine.

If it is assumed that the mass of saline crystals would contain a void space of 30 per cent of its volume and the resulting mother liquor had a specific gravity of 1.3, the weight of the brine solution contained in 1 cubic foot would be 24.4 pounds. If we assume the specific gravity of the salines to be 1.9, the weight of the brine absorbed would be 29.0 per cent of the weight of the dry saline material, or 22.4 per cent of weight of brine and salt. This would not be sufficient to absorb all of the mother liquors at the final stages of crystallization.

Interpreting the chemical data obtained by the deep bore and the three surface bores, and using the criteria which have been established, I have reached the conclusion below.

The initial stages of Searles Lake were similar to Lake Lahontan. The lake at this period might have been over 1,200 feet in depth, and there is no reason to suppose that it was other than fresh. The drying up of the lake must have extended over a great length of time. The first part of the record, 600 to 627 feet, indicates that the lake had reached saturation and had begun to deposit salines. The brines at this stage deposited salines low in carbonates, high in chlorides and sulphates, and noticeably high in potassium. Either sedimentation proceeded at a rapid rate or crystallization must have been slow. The latter is more likely the case. At a depth of 586 to 596 feet the brine was diluted sufficiently to stop crystallization. The saline content of this brine figures out as follows:

	Per cent.
Potassium chloride.....	5.48
Sodium chloride.....	59.15
Sodium sulphate.....	29.04
Sodium carbonate.....	1.31
Sodium bicarbonate.....	2.44

During this stage carbonates were accumulating in the lake waters. Concentration of the water followed and salines were again deposited (575 to 580 feet; samples Nos. 223 and 224). From 427 to 540 feet salines were steadily deposited and inclosed by the sediments. The brine at this stage must have approximated in composition evaporated Owens Lake water, for carbonates are found in increasing amounts. The conditions must have approximated the trona period. During this period the rate of crystallization exceeded sedimentation. The content of potassium is high. From 227 to 427 feet the record is lacking. At 227 feet conditions approaching the sulphate period are indicated. The salines are low in carbonates and high in sulphates and chlorides. Potassium still remains high and amounts to 3.72 per cent of the saline residue (sample 211). From 80 to 227 feet the record is lacking.

The central bore of the Dolbear series indicates that at 65 to 79 feet depth the trona period occurred, followed at 50 to 65 feet by the sodium chloride period, and this was followed by a sulphate period at 35 to 50 feet. An interruption is indicated here. More than likely a humid period diluted the lake and stopped crystalli-

¹ From experiments upon slime cakes formed by vacuum filtration, I have found that the densest portion of a slime cake, formed under a pressure of 11 pounds per square inch, has a specific gravity of 1.84, and a water content of 27.9 per cent. Using these figures and assuming a brine of 1.3 specific gravity and a saline content of 30 per cent by weight would give a saline content for the dried cake of 13 per cent. This figure can be used comparatively with the one obtained by calculation. I am inclined to use the figure obtained by the previous calculation, since the slime experiment does not take into account the time element nor the greater pressures to which mud in the bottom of a lake would be subjected.

zation. From 18 to 35 feet a sulphate period followed, and this in turn was closed by the chloride period. Two periods of desiccation are indicated in the closing stages—the present one and one (recent geologically) at some unknown time before.

The marginal bore also indicates an interruption in the desiccation. A passage from the trona to the sulphate period was followed by a trona period. The last trona period passes gradually into the chloride period, with possible indications of another interruption at 25 to 30 feet depth. More or less sedimentation marked this portion of the deposit. The final capping with a mud layer 13 feet thick closed the cycle of events at this point.

The important question of what became of the residual mother liquor which must have covered the saline bed at the close of the last desiccation period has not been discussed. The suggestion by J. Walther, quoted by Clarke,¹ that residual bitterns might be absorbed by wind-blown sands, and by capillarity brought to the surface, wind eroded, and carried away, occurs as a plausible explanation. Undoubtedly some such action took place locally, but it could not have been on a sufficient scale to account for the removal of all of the mother liquors. The fact that the upper portion of the central bed contains a large proportion of sodium chloride and a brine lower in potassium content than the brine beneath suggests that the closing stages of desiccation must have closely paralleled present conditions in Death Valley. Searles Lake, in passing through the last stages of desiccation, must have deposited sodium chloride, as well as other salts, over a much larger area than that occupied by the present central bed. The shallow lake of mother liquor occupying the central depression must have received periodic accessions of saline material from these marginal deposits. Continued over a long time the effect would be to build up a bed of saline material in which the content of potassium salts would not be conspicuous and which would contain the diluted original mother liquor absorbed in its interstices. Continual accession of salines from the margins would result in a top bed of saline material comparatively poor in potassium salts. This explanation appears to me to be the most reasonable.

The central salt bed over practically the whole area of 12 square miles contains in its interstices a brine which, below the top bed of sodium chloride, is characterized by a relatively high content of potassium. According to Dolbear, the brine containing the high content of potassium salts is confined to a vertical horizon of some 47 feet. Below this horizon the brines contain relatively less potassium salts. The following is an analysis of the rich brine taken from bore hole A7 on the N-S center line and just south of the center of the salt area:

Analysis of brine from Searles Lake, expressed in percentages of the anhydrous residue.

[Sample collected by E. E. Free; analysis by W. H. Ross, of the Bureau of Soils.]

Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Per cent.
Na.....	33.57	Mn.....	None.	I.....	0.004
K.....	6.06	Cu.....	None.	SO ₄	12.96
Li.....	.01	Al ₂ O ₃	.012	CO ₂	6.70
Rb.....	None.	Fe ₂ O ₃	.003	PO ₄	.30
Ca.....	None.	SiO ₂	.023	NO ₃	None.
NH ₄	None.	Cl.....	37.02	AsO ₃	.083
Mg.....	Trace.	Br.....	.094	B ₄ O ₇	3.00

This is of the nature of a residual mother liquor. It consists of chlorides in greatest amount, sulphates, carbonates, practically no bicarbonates, and borates. It is conspicuous by the presence of bromine, iodine, and arsenious oxide. The sodium-potassium ratio in this brine is 5.5. The average of 14 of the samples from the deep boring, omitting results upon crystals and Nos. 217 and 215, is 15.5. This would indicate that the water collected in the early stages of Searles was not unlike that of the present lakes in which the sodium-potassium ratio is 20.

Supplementary analyses by A. R. Merz upon samples collected by E. E. Free are given in Table XXIX (Appendix).

The brine body is contained in a mass of coarsely crystalline material, more or less honeycombed. The portion occupying the central mass of salt is richest in potassium salts and borates below the upper salt crust of 18 feet thickness and above the 65-foot level.

¹ Bul. No. 491, U. S. Geol. Survey, p. 224.

Dolbear¹ presents the following estimate of quantities for the 47-foot bed of brine and crystallized salts:

In brine:		Tons.
Potassium chloride.....		6,455,600
Anhydrous borax.....		1,900,000
Sodium carbonate.....		6,630,000
In saline material:		
Potassium chloride.....		23,900,000
Anhydrous borax.....		15,200,000
Sodium carbonate.....		108,500,000
Sodium bicarbonate.....		42,700,000
Weight of brine.....		144,000,000
Weight of salts.....		656,000,000

The figures given are conservative. Dolbear states that the brine contains 4.49 per cent of potassium chloride. The result upon the Bureau of Soils samples is less than this, 3.51 per cent being obtained by their analyses.

Comparison of saline residues.

[Per cent of anhydrous residue.]

	Ca.	Mg.	Na.	K.	Cl.	Br.	I.	SO ₄ .	CO ₂ .	PO ₄ .	AsO ₄ .	B ₂ O ₇ .
Searles.....	0.0	Trace.	33.57	6.06	37.02	0.094	0.004	12.93	6.70	0.30	0.083	3.00
Death Valley.....	.002	0.003	36.12	2.63	53.70			5.62	.18			Present.
Silver Peak.....	1.05	.64	35.14	2.94	58.86			1.26	.30			Trace.
Owens ^{1 2}	.02	.01	38.09	1.62	24.82			9.93	24.55	.11	.05	.14
Mono ²	.04	.10	37.93	1.85	23.34			12.86	23.42			.32
Great Salt Lake ²	.33	2.22	33.31	1.92	55.36			6.53	.07			
Pyramid ²	.25	2.28	33.84	2.11	41.04			5.25	14.28			
Winnemucca ²	.55	.49	36.68	1.94	47.88			3.76	7.93			
Walker ²	.90	1.56	34.83		23.77			21.29	17.34			

¹ Owens Lake, nitrate=0.45 per cent.

² Clarke, Bul. No. 491, U. S. Geol. Survey, pp. 144-146.

Comparison of the saline residues from residual brines, from lake waters in which concentration has proceeded to a considerable extent and from lake waters in which concentration is in initial stages is shown in the accompanying table. Regional differences are, of course, apparent, and must be considered. With the exception of the calcium and magnesium content, the saline residue of the Death Valley brine closely approximates that from Great Salt Lake. Silver Peak is lower in sulphates but more nearly approximates Death Valley. Mono and Owens Lake closely compare and, save for the higher proportion of carbonate, approximate the Searles brine. The residues of Pyramid and Winnemucca are relatively higher in chlorides and lower in sulphates than Mono and Owens. The residue of Walker Lake is high in sulphates and carbonates and lower in chlorides than Pyramid or Winnemucca. Little concentration of potassium is indicated in the last two groups, but decided concentration is shown in the first group, and borates are progressively concentrated from the third to the first group. Nitrate is concentrated from the third to the second group. Great Salt Lake is the only water in the second and third groups in which precipitation of salines is taking place. This residue can be considered intermediate between groups 1 and 2.

COLUMBUS MARSH.

Columbus Marsh is near Coaldale, Esmeralda County, Nev. The area is 32.5 square miles. It receives the drainage of Fish Lake Valley from the south and the basin immediately surrounding the marsh. Two shore lines are present, one about 60 feet above the flat and the other, reported by E. E. Free, at 104 feet. The lake could not have been of much greater extent than the marsh. The comparative shallowness would indicate a relatively small amount of salines. The present surface is a broad plain roughened by very small, more or less rounded, hummocks. There is very little salt in the form of crusts. The surface is dry enough at most times to support a road

¹ Eng. and Mining Jour. cited before.

across the central part. The marsh has some of the characteristics of Rhodes Marsh. No chemical data are available, except those published by the United States Geological Survey in the press bulletin noted below.¹ In this report Gale describes the discovery of a mud at depths from 18 to 38 feet, containing a small percentage of soluble salts, and a high content of potash in the soluble salts. The analyses follow:

Analyses of samples from Columbus Marsh, Nev.

[W. B. Hicks, analyst.]

No. of sample.	Depth.	Total soluble salts.	Percentage of total soluble salts.		
			K.	K ₂ O.	KCl.
	<i>Feet.</i>	<i>Per cent.</i>			
1.....	1	17.20	1.67	2.01	3.18
2.....	3	9.07	2.55	3.07	4.85
3.....	4½	8.88	2.48	2.99	4.73
4.....	9	10.15	2.95	3.55	5.62
5.....	12	1.93	(¹)	(¹)	(¹)
6.....	18	5.17	16.64	20.05	31.72
7.....	27	6.30	20.90	25.18	39.83
8.....	30	6.17	13.69	16.49	26.09
9.....	33-38	6.22	17.12	20.63	32.64

¹ Not determined.

The results are unlike anything as yet reported and their full significance can not be determined without further investigation. The low saline content, 6 per cent, together with the average potassium content, 17.09 per cent (average of results from 18 to 38 feet), would give a potassium content of 1 per cent on the original material dried. The conditions very much suggest that in this occurrence we have a sample of the absorption of a residual mother liquor by wind-blown desert material. It is a matter of doubt whether this mud and brine could be utilized. The removal of a brine from a mud would be attended with greater difficulties than would be the case with the Searles brines. In the latter case the brines are contained in a coarsely crystalline mass and there is comparatively free movement of the brines. In the former case (a more or less compact mud) there would be slow movement of the brines. The most significant thing is not so much the workability of the muds as their high potassium content and the possibility of a larger brine deposit equally rich in potassium at depth. The results of further work in this locality will be awaited with interest. Marsh deposits of borax were worked at Columbus, but at present nothing is being done. These deposits do not show any points of special interest.

DIXIE VALLEY.

Dixie Valley, called Osobb, or Salt Valley, in the Fortieth Parallel Survey Report, lies just east of the Sweetwater range in Churchill County, Nev. It was occupied by a shallow lake which at its maximum covered the present valley to a depth of 150 feet. The Railroad Valley Co. explored this area for potash salts by a number of bores, some extending to 100 feet in depth. The bores showed in the central depression a bed of salt 11 feet thick, mixed with mud, and below this a bed of black mud, 33 feet thick, containing a few crystals of gaylussite. The brine body underlying the salt contains salines composed of 92 per cent sodium chloride, 4 per cent sodium carbonate, and from traces to 0.5 per cent potash. The saline efflorescences consist of sodium carbonate and sulphate, but no potash. The highest content of potash found was 1 per cent of the soluble salts.

Through the courtesy of the Railroad Valley Co. and E. E. Free the results of several bores and the chemical examination of the brines from the bores are presented in the following table:

Record of drill hole No. 1, Dixie Valley.

[Located slightly northeast of the center of sec. 30, T. 23 N., R. 36 E., being the southwest corner of claim No. 42.]

	Feet.	
Salt.....	0	to 1
Black salty mud.....	1	to 2
Salt with some mud.....	2	to 3.5

¹ Press Bul., U. S. Geol. Survey, Feb. 12, 1913.

	Feet.
Black mud with scattered salt crystals.....	3.5 to 5
Salt.....	5 to 7
Black mud with scattered salt crystals.....	7 to 8
Black salty mud, without crystals.....	8 to 11
Gray clay with occasional layers containing small salt crystals.....	11 to 15
Black clay.....	15 to 16
Gray clay.....	16 to 22
Dry, yellowish clay, occasionally slightly gritty.....	22 to 26.5
Gray clay.....	26.5 to 29
Black clay and mud.....	29 to 33.5
Black mud with many layers containing small crystals of gaylussite.....	33.5 to 49
Black mud and clay without crystals.....	49 to 98

Record of drill hole No. 2, Dixie Valley.

[Located slightly southeast of the center of the west line of sec. 19, T. 23 N., R. 36 E., being the northeast corner of claim No. 5.]

	Feet.
Salt.....	0 to 1
Black mud.....	1 to 2
Black mud with many salt crystals.....	2 to 3
Salt.....	3 to 4.2
Salt with some black mud.....	4.2 to 6.5
Grayish clay with some salt crystals.....	6.5 to 8
Yellow clay containing some salt crystals in the upper portions. Lower portions dry and tough.....	8 to 19
Tough gray clay.....	19 to 22
Black mud and clay becoming tough and dry in the lower portions....	22 to 94.5

Record of drill hole No. 3, Dixie Valley.

[Located slightly northeast of the center of sec. 13, T. 23 N., R. 35 E., being the southwest corner of claim No. 46.]

	Feet.
Salt.....	0 to 0.25
Black mud.....	0.25 to 1.2
Salt.....	1.2 to 2
Black mud.....	2 to 2.5
Salt with some mud.....	2.5 to 6
Salt.....	6 to 6.5
Black mud with salt crystals.....	6.5 to 10.5
Yellow clay.....	10.5 to 14.5
Thin layer of salt with some flow of water.....	14.5 to 14.7
Yellow clay somewhat gritty in upper portion.....	14.7 to 18
Gray clay.....	18 to 25
Black mud becoming dry and tough in lower portion.....	25 to 83

Analyses of brines from drilled holes.

Sample.	Depth.	Conventional combinations, grams per 100 c. c.					Total solids on evaporation, grams per 100 c. c.	K ₂ O, per cent of total solids.
		NaCl.	Na ₂ SO ₄ .	Na ₂ CO ₃ .	KCl.	Total by addition.		
Hole No. 1:								
4.....	Feet.							
2.....	Surface.	27.01	5.02	3.83	0.41	36.27	37.62	0.69
1.....	4	26.37	4.39	4.12	.46	35.34	38.70	.75
50.....	26	26.91	4.03	2.65	.19	33.78	35.10	.34
51.....	64	25.08	4.37	3.30	.28	33.03	32.80	.54
52.....	71						34.48	.38
53.....	81						34.64	.42
54.....	91	23.71	3.73	3.48	.24	31.16	31.57	.48
55.....	98						31.70	.41
Hole No. 2:								
56.....	2.5						36.48	.54
57.....	6.5						35.82	.47
58.....	10.5						35.63	.43
59.....	21						35.19	.33
60.....	28						35.50	.40

Analyses of brines from drilled holes—Continued.

Sample.	Depth.	Conventional combinations, grams per 100 c. c.					Total solids on evaporation, grams per 100 c. c.	K ₂ O, per cent of total solids.
		NaCl.	Na ₂ SO ₄ .	Na ₂ CO ₃ .	KCl.	Total by addition.		
Hole No. 2:	<i>Feet.</i>							
60.....	38						33.24	0.33
61.....	55	28.02	4.69	3.25	0.31	36.27	36.29	.54
62.....	67						35.66	.60
63.....	78						36.47	.50
64.....	85						34.34	.51
65.....	91.5						36.02	.57
66.....	94.5	27.79	4.56	3.53	.33	36.21	37.16	.56
Hole No. 3:								
67.....	1.3						34.99	.28
68.....	2.5	28.99	3.65	1.77	.15	34.56	34.81	.27
69.....	5.5						35.00	.27
70.....	11						35.60	.25
71.....	14.5						33.92	.25
72.....	25						35.79	.23
73.....	35						34.65	.19
74.....	45	28.42	4.68	2.21	.16	35.47	35.30	.29
75.....	55						35.77	.35
76.....	63						35.01	.30
77.....	71						28.70	.25
Average.....		26.92	4.34	3.12	.28	34.67	34.96	.40

The section shown by the borings indicates very much the same conditions and history as were described in the Silver Peak Marsh. We have here the case of a shallow lake passing through alternate periods of desiccation. At times desiccation proceeded to such a point as to cause concentration of the lake waters and deposits of salt. More than likely each salt bed was marked by the evaporation of the lake and the formation of a salt playa.

RAILROAD VALLEY.

Railroad Valley is in the northeastern part of Nye County, Nev., about 130 miles northeast of Tonopah and 80 miles southwest of Ely. It is 10 to 20 miles wide from east to west and somewhat over 100 miles long north to south. The flat, central portion of the valley has an area of about 200 square miles. The drainage basin is about 6,000 square miles. Free states that shore-line indications show a lake level varying from 50 to 300 feet above the present bed of the dry lake. A number of playas, covered by thin salt crusts, occupy the bed of the present dry lake. (Plate IV, fig. 2.) Analyses of these crusts and the accompanying brines have been given in a previous section, and many of them show a high potassium content. The Railroad Valley Co. put down a bore 1,204 feet deep on the east-west half-section line of sec. 2, T. 8 N., R. 56 E. The bore is about one-fourth mile west of the west north-south line of sec. 1, same T. The log of the bore is herewith presented.

Log of potash drill hole No. 1, Railroad Valley, Nye County, Nev.

[Drilling commenced Mar. 17, 1912; ceased Aug. 27, 1912. All operations in charge of D. H. Walker.]

	<i>Feet.</i>
Mixed clay and sand, mostly sand (fresh water, not artesian).....	1- 32
Quicksand (fresh water).....	32-103
White clay.....	103-104
Alternations of quicksand and clay. Some fine gravel among the quicksand (artesian waters in sands, especially at 128 feet).....	104-136
Clay.....	136-178
Very fine quicksand (artesian water, especially at top of division).....	178-214
Clay.....	214-220
Quicksand with fine gravel (artesian water).....	220-222
Rapid alternations of sand and brownish clays (artesian water in most of the sands, especially at 250 feet).....	222-255
Clay.....	255-260
Quicksand.....	260-264

	Feet.
Rapid alternations of sand and brownish clay.....	264-275
Tough clay.....	275-285
Sand with coarse and fine gravel, including pebbles $\frac{3}{4}$ inch in diameter (artesian water).....	285-290
Very fine brownish sand.....	290-305
Tough sticky clay.....	305-336
Rapid alternations of clay and quicksand, the latter containing a little fine gravel (artesian water).....	336-340
Light-colored clay.....	340-350
Quicksand, probably with occasional thin layers of clay.....	350-375
Tough gray clay.....	375-390
Quicksand (small artesian flow).....	390-391
Tough gray clay.....	391-418
Quicksand (small artesian flow).....	418-419
Brown clay.....	419-429
Sand (small artesian flow).....	429-430
Hard brown clay with occasional very thin sand streaks.....	430-445
Gray clay.....	445-459
Very soft yellowish clay.....	459-461
Quicksand (artesian water).....	461-462
White sticky clay.....	462-463
Blue-green clay.....	463-470
Very fine quicksand (artesian water).....	470-471
Lead-colored clay.....	471-478
Very fine sand.....	478-479
Blue-green clay.....	479-480
White clay.....	480-490
Blue-green clay with occasional thin sand streaks.....	490-493
Gray clay.....	493-500
Blue-green clay, with occasional thin streaks of coarse sand.....	500-504
White clay, fragments showing jointed structure.....	504-511
Tough, blue green clay.....	511-519
Quicksand (artesian water smelling of sulphuretted hydrogen).....	519-520
Gray clay.....	520-523
Gray clay with occasional thin strata of sand (artesian waters in all sands. Waters smell of sulphuretted hydrogen).....	523-529
Gray clay.....	529-533
Very fine quicksand (artesian water smelling of sulphuretted hydrogen).....	533-534
Blue-green clay.....	534-539
Quicksand with some rather coarse gravel (strong artesian flow. Water carries no sulphuretted hydrogen).....	539-541
Sticky yellowish clay.....	541-549
Tough white clay.....	549-554
Blue-green clay.....	554-556
Very tough white clay.....	556-560
Quicksand.....	560-561
Blue-green clay.....	561-583
White clay.....	583-586
Quicksand (small artesian flow).....	586-587
Clay.....	587-596
Alternations of clay and black sand (small artesian flows in sands, espe- cially at 605 feet).....	596-609
Tough white clay.....	609-620
Gray clay.....	620-637
Sand.....	637-638
Very sticky clay.....	638-655
Light-colored greenish clay.....	655-657
Very tough white clay.....	657-676
Quicksand (small artesian flow).....	676-677
Rapid alternations of clay and sand (very little water).....	677-680
White clay.....	680-691
Rapid alternations of clay and sand.....	691-700
Brownish clay.....	700-719
Sand (very small artesian flow).....	719-720
Brownish clay.....	720-738
Rapid alternations of quicksand and clay, the former carrying a little coarse gravel (small artesian flows).....	738-746

	Feet.
Very tough brownish clay.....	746-759
Rapid alternations of sand with brownish clay (small artesian flows in the sands).....	759-771
Hard brownish clay.....	771-785
Quicksand (artesian water).....	785-786
Clay.....	786-790
Sand (small artesian flow).....	790-791
Brownish clay.....	791-798
Rapid alternations of sand and clay.....	798-805
Hard brown clay.....	805-816
Quicksand and gravel (artesian water).....	816-822
Hard white clay.....	822-824
Rapid alternations of brownish quicksands and clays. Some gravel $\frac{1}{4}$ inch in diameter in the sands (very strong artesian flows in sands. Temperature of water, 22° C.).....	824-846
Brownish clay.....	846-850
Sand and gravel.....	850-855
Rapid alternations of sand and clay.....	855-858
Very fine sand.....	858-862
Rapid alternations of sand and brownish clay.....	862-865
Gray clay.....	865-876
Coarse gravel (artesian water).....	876-878
Very fine sand.....	878-882
Rapid alternations of clay and sand.....	882-886
Gray clay.....	886-889
Fine quicksand (artesian water).....	889-892
Rapid alternations of sand and brownish clay.....	892-899
Gray clay.....	899-908
Sand and coarse gravel (very strong artesian flows).....	908-910
Very fine sand.....	910-922
Sand and coarse gravel (small artesian flow).....	922-924
Light-gray clay.....	924-934
Fine sand.....	934-941
Gray clay.....	941-945
Sand.....	945-947
Yellow clay.....	947-953
Gray clay.....	953-967
Sand and gravel (small artesian flow).....	967-969
Brown clay with occasional very thin streaks of sand.....	969-980
Brown clay.....	980-1,002
Fine sand (dry).....	1,002-1,003
Hard brown clay.....	1,003-1,049
Sand (dry).....	1,049-1,050
Brown clay.....	1,050-1,078
Quicksand (probably dry).....	1,078-1,079
Brown clay with occasional very thin streaks of sand.....	1,079-1,085
Tough brown clay.....	1,085-1,131
Very thin sand streak (dry).....	1,131
Brown clay.....	1,131-1,140
Sand cemented by calcium carbonate, believed to be lake tufa.....	1,140-1,144
Sticky gray clay.....	1,144-1,165
Rapid alternations of clay and sand.....	1,165-1,175
Lime-cemented sand. Probably lake tufa.....	1,175-1,190
Reddish clay with occasional very thin sand streaks (dry).....	1,190-1,204
Fine sand, probably quick.....	1,204

The casing having stuck hopelessly in the cemented sand between 1,175 and 1,190, it was impossible to carry the hole deeper.

The bore does not show either beds of salines or brines. The material obtained consists of muds, silts, clays, and quicksands. Artesian water was encountered at many points. The nonpenetration of saline beds by a single bore hole is not surprising when one considers the area of the central depression. The fact that artesian flows were encountered would argue that the bore was considerably without the central mud area, or the area of lowest depression. The former lake in evaporating may have separated into several parts, and thus we might have several saline beds of moderate thickness in the central area. The general silting of the whole area would render it

extremely difficult to locate these beds. Until proved otherwise by a number of bores, Railroad Valley must be looked upon as a possible source of buried salines. The question as to whether these salines will be characterized by a high potassium content is an open one. The finding of surface crusts and brines of relatively high potassium content proves nothing as far as we know at present about the buried salines and brines. A possible explanation of the high potassium content in the surface salines and brines may be found in the fact that there are a number of hot springs in this area, and these may have been responsible for the surface salines. Until analyses of the waters of these springs are available this is only conjecture.

SAND SPRINGS FLAT.

Sand Springs Flat area is described on the United States Topographic Sheet as "Eight-mile Flat" and "Fourmile Flat." It was called "Alkali Valley" in Russell's Monograph on Lahontan Lake. It lies 11 miles southeast of Fallon, in Churchill County, Nev. The area is about 37 square miles. It has a peculiar interest in that a bay of Lake Lahontan once occupied the area. The highest level of Lake Lahontan was 439 feet above the present flat, elevation 3,961. The desiccation of Lake Lahontan would have left a shallow lake upon the flat, and this, on evaporation, would have left a bed of salines. Russell states that the salt bed is from 3 to 5 inches thick near the margin and in the central portion is not less than 3 feet thick. Rain water has collected the salines in the southeast end of the flat. Russell¹ states that after rains a shallow brine lake of several inches depth and about 15 square miles in area occupies this portion. No notable amounts of potassium have been reported from the salines of this area.

SEVIER LAKE.

Sevier Lake is in west-central Utah, Millard County. It is of some interest in that it was formerly a part of Lake Bonneville and for a long time was occupied by a shallow lake, which in recent times has dried up. Gilbert² describes the history of this lake. From his account I take the following:

Sections of the saline beds in the central and marginal portions of the dried lake.

Central.	Marginal.
1. Top. Sodium sulphate, 2 inches	1. Top. Sodium chloride crust, $\frac{1}{2}$ inch.
2. Sodium sulphate with some sodium chloride, 1 inch.	2. Sodium chloride with sodium sulphate and magnesium sulphate—free crystals mingled with water, $\frac{1}{2}$ inch.
3. Sodium sulphate, 2 inches	3. Sodium sulphate with sodium chloride, a crust of coherent crystals, $\frac{1}{2}$ inch.
4. Gray clay containing woody fiber, 2 inches.....	4. Sodium chloride with sodium sulphate; incoherent crystals mingled with water, $\frac{1}{2}$ inches.
5. Fine sand containing fresh water shells, 6 inches.	5. Sodium chloride, with sodium sulphate, chemically identical with No. 2, but fine-grained and with the consistence of an ooze; color white above, with occasional passages of pink and green beneath, $\frac{1}{2}$ inch.
6. Gray clay.....	6. Dark-gray mud, 2 feet.

The analyses upon these from the same reference are given in the succeeding table:

Constituent.	Center.	Margin.	Brine.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Sodium sulphate.....	84.6	14.3	15.5
Sodium carbonate.....	.4		
Sodium chloride.....	7.0	80.62	72.1
Calcium sulphate.....			.5
Magnesium sulphate.....		5.5	
Magnesium chloride.....			11.9
Potassium sulphate.....		.7	
Water.....		3.6	
Insoluble.....		.1	
	100.00	100.00	100.00

¹ Monograph No. 11, U. S. Geol. Survey, p. 235.

² Monograph No. 1, U. S. Geol. Survey, p. 244.

The accumulation of sodium sulphate in the center is of interest. The absence of potassium compounds in the brine and the low content in the marginal deposits are conspicuous. The accumulations in Sevier Lake are undoubtedly due to comparative recent action. Deeper bores would have revealed more of the history of the basin and perhaps beds of salines characteristic of the Bonneville period would have been discovered.

BLACK ROCK DESERT, NEVADA.

The Black Rock and Smoke Creek Deserts are of notable extent. The northern extension of Lake Lahontan occupied this area, but no surface deposits of salines have been discovered. Some saline crusts can be found, but these are of little importance. A 500-foot well was put down at Sulphur, on the line of the Western Pacific Railroad and on the edge of the mud flat, but neither oil nor salines were found. West of Gerlach, salt is produced in small quantities by the evaporation of brines obtained from shallow wells.

But few data of a chemical nature are available for this area. In the vicinity of Gerlach samples of mud were obtained from a shallow auger hole. From the same vicinity water samples were also obtained. The analytical results are given below. The muds show a high content of salines, and these consist of chlorides and sulphates, together with small quantities of carbonates. The potassium content is about what would be expected. The mud is a tenacious clay. The waters are somewhat similar in composition to the salines contained in the clays.

Analyses of saline crust and muds from the Black Rock Desert, Nevada.

Sample and depth.	Percentage of total soluble salts.								Total soluble salts.
	Ca.	Mg.	Na.	K.	CO ₃ .	HCO ₃ .	SO ₄ .	Cl.	
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
Surface crust.....	1.56	0.02	34.41	1.12	0.05	0.10	21.36	40.99	59.68
Muds: ¹									
0-1.25 feet.....	.78	.02	35.90	2.32	.16	.33	6.85	53.63	18.31
1.25-2.5 feet.....	.71	.03	36.09	2.06	Tr.	.66	7.84	52.57	23.19
2.5-3.75 feet.....	.63	.02	36.32	2.28	0	.49	4.97	55.37	24.83
3.75-5 feet.....	.68	.03	36.48	2.33	0	.35	4.07	56.03	34.47

¹ Average ratio Na to K in muds is 16.

Analyses of waters from the Black Rock Desert, Nevada.

Sample.	Percentage of total solids on evaporation.								Solids on evaporation.
	Ca.	Mg.	Na.	K.	CO ₃ .	HCO ₃ .	SO ₄ .	Cl.	
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>Parts per 100,000.</i>
Water from surface trench.....	0.48	0.08	36.03	1.49	0.10	0.46	4.64	55.11	5,209
Average, 4 springs.....	2.11	.06	32.08	2.73	.19	2.97	8.13	47.57	428.4
Boiling hot spring.....	2.48	Tr.	32.63	2.70	0	1.35	11.25	47.93	444

[Saline clays and crust from point 1.5 miles northeast of Gerlach, Nev. Water from surface trench from same place. Samples by W. S. Palmer; analyses by J. A. Cullen.]

The waters from the four springs averaged were taken 0.25 mile from Gerlach. The temperature of these springs ranged from 16.1° to 32.2° C. Samples by W. S. Palmer; analyses by S. C. Dinsmore.

The boiling spring was three-fourths mile northwest of Gerlach. Sample by W. S. Palmer; analyses by J. A. Cullen.

BURIED DEPOSITS OF SALINES.

The deposits resulting from the desiccation of Searles Lake are exposed on the surface and their discovery was a simple matter. Geological reasoning indicates that the conditions exemplified by Searles must have been repeated at other places in the Great Basin. Evidences of Quaternary lakes are to be found in a number of places, but not in all places do we find the expected saline deposits. The largest Quaternary lake basin, excepting Bonneville, is Lahontan, and it is now occupied by Pyramid, Walker, Humboldt, Carson, and Winnemucca Lakes. Unlike Mono,

Owens, and Great Salt Lakes, the waters of these lakes are comparatively fresh. Geological evidence goes to show that Lahontan Basin must have been the locus for an accumulation of salines for a long period. The inconsequential surface accumulations of salines in this basin, coupled with the anomalous condition of the present lakes, led Russell¹ to propose the following hypothesis:

"After the last great rise of Lake Lahontan there was a long-continued episode during which its basin was more arid than at present. Evaporation during that time is thought to have been equal to precipitation, and the residual lakes were reduced to the playa condition—that is, the remnants of the great lake gathered in the lowest depressions of its basin were annually or occasionally evaporated to dryness, and their contained salts were precipitated and either absorbed by the clays, etc., deposited at the same time, or buried beneath such mechanical deposits. This process may be observed in action in many of the valleys of Nevada in which ephemeral lakes occur. The broad naked playas of Black Rock, Smoke Creek, and Carson Deserts, as well as the level floors of the basins occupied by Pyramid, Winnemucca, and Walker Lakes, are in support of this hypothesis. Should the lakes just mentioned be evaporated to dryness, playas would be left similar to those in neighboring valleys of less depth.

"It is beneath the level floors of these valleys and lake basins that the more soluble salts once dissolved in the waters of Lake Lahontan are buried. Borings at certain localities might reveal the presence of strata of various salts, but in most cases they are probably disseminated through great thicknesses of clay, sand, and other mechanical sediments."

Russell's² admirable discussion of the freshening of lakes by desiccation, together with the later review in the reference cited above, leaves little to be added. Under the discussion of the present and past rate of accumulation of saline material it was shown that over some 95,000 square miles area a present accumulation of approximately 3,000,000 tons of salines per annum is taking place, and that in the humid period of the Quaternary this rate might have been more than four times as large. No even approximate estimate of Quaternary time for the basin has been made, and consequently no estimate of the probable quantity of salines can be made.³ That it was large goes without saying. While absolute proof of Russell's hypothesis has not been made, its probability is almost beyond question. If we admit it, the pertinent questions arise: Where are these deposits, and what is their probable value as a source of salines? The answer to the first question has been given by Russell. The answer to the second is given in part by the chemical studies of the deposits in Searles and Columbus Marshes, Death and Dixie Valleys, and the partially concentrated solutions of Mono, Owens, and Great Salt Lakes.

Gilbert shows that Lake Bonneville overflowed and discharged its waters, together with their salines, into river waters which eventually found their way to the ocean. On account of the prevalence of older sedimentaries in the Bonneville basin and the low content of potassium in the brines of Great Salt Lake, together with the above fact, the Bonneville basin is not looked upon as a very favorable place for the discovery of the more valuable salines. On the other hand, Lake Lahontan and the Quaternary basins of the west, central, and southwest parts of the Great Basin have never reached an outlet. The regional rocks are largely volcanic, and consequently these Quaternary areas have been looked upon favorably as a possible source of valuable salines.

If we consider that the present topography of the Lahontan Basin is, in a measure, a counterpart of the topography at the end of the final desiccation period, then we must conclude that the present lakes are holding within their shores the former areas of maximum depression, and, consequently, a part of the saline accumulations is buried in the sediments and beneath the waters of the present lakes. The remainder must be sought for in the mud playas and basins contiguous to the present lake basins.

An examination of Russell's map of Lake Lahontan at its highest water stage⁴ indicates a division of the lake into five major lakes, Carson Lake, Black Rock Desert, Pyramid, Winnemucca, Walker, and Honey Lakes, given in the order of their mag-

¹ Bul. No. 530 A, U. S. Geol. Survey, p. 16.

² 11th Annual Report, U. S. Geol. Survey, p. 244.

³ Russell estimates the duration of the post-Lahontan period to be less than 300 years. Gilbert estimates that at the present rate of accretion some 34,000 years would be necessary to account for the sodium chloride in Great Salt Lake. I have calculated the following: At present rates of accretion it would take 18,576 years for the chlorine accumulation in Owens Lake; 9,028 years for the chlorine accumulation in Mono Lake (assuming the same per square mile annual rate of accumulation that was determined for the Truckee Basin); 4,529 years for the chlorine accumulation in Pyramid Lake; 840 years for the chlorine accumulation in Walker Lake, and 6,452 years for the nitrate accumulation in Owens Lake. The impossibility of determining the average rate of accumulation renders such determinations of little value.

⁴ Eleventh Annual Report, U. S. Geol. Survey, pl. 5, p. 32, and the U. S. Geol. Survey topographic sheets, Granite Range, Nev.; Disaster, Nev.; and Honey Lake, Cal.

nitude. Each of these lakes on evaporation must have left deposits of salines. It is not improbable that in some cases several separate deposits were left. The Black Rock Desert is at present a comparatively level plain. As far as known, no notable quantities of salines have been discovered. That they exist in some places beneath the desert sand or absorbed within the muds is probable. The great area of this desert (1,600 square miles approximately within the 4,000-foot contour) and its extreme flatness would render the search for these deposits difficult. Pyramid Lake, the deepest of the present lakes, is 360 feet deep. This basin must have been

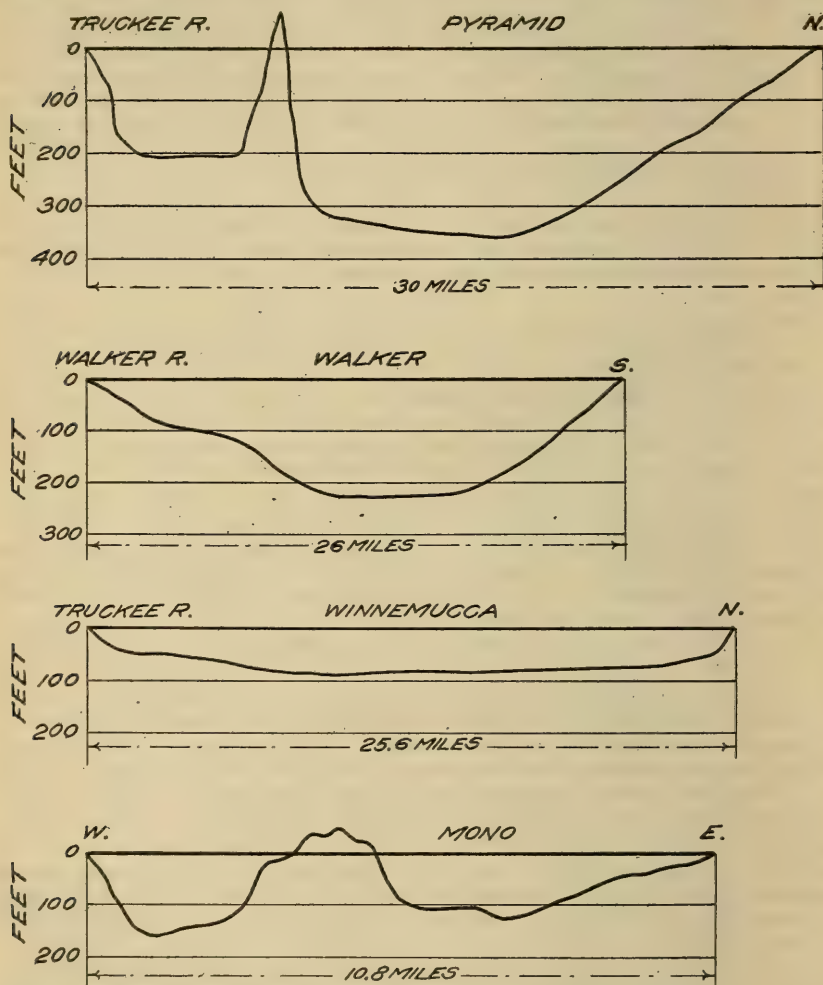


FIG. 7.—Profiles of Pyramid, Winnemucca, Mono, and Walker Lakes.

the deepest of the Quaternary basins. It is an open question whether the waters of Black Rock Desert or those of Carson Lake drained into this basin. Present topographic conditions would indicate no particular drainage from either place. In fact, if we consider that Pyramid Lake receives the largest stream we would conclude that the overflow from this lake during the intermediate stages of evaporation would have been into the Black Rock Desert and into the Carson. Topographic conditions seem to indicate that Walker Lake did not drain in the direction of Carson Lake. The lowest pass between Carson and Pyramid Lakes is at Ragtown, and at an elevation of 4,100 feet. If we assume that the Carson and Truckee Rivers had flows relatively the same as at present, we should expect Pyramid Lake to discharge some of its contents into the Carson. There are no present evidences as to the direction of flow from

one lake to the other, and perhaps the assumption that there was no considerable flow from one lake into the other is the nearest to the fact. This would lead us to conclude that in each of these basins we might expect salines at depth.

The present depth of Pyramid and Walker Lakes, needless to say, would preclude exploration work in these localities. The profiles of Pyramid, Winnemucca, Mono, and Walker Lakes are shown in figure 7. These profiles show the deepest portions of the lakes to be in the central part or away from shores or inlet streams. Topographic evidence goes to show that the saline deposits in Black Rock Desert must have been spread over a great area and must have been relatively thin. The difficulty of prospecting or exploring has been commented upon.

Carson Lake is comparatively shallow and would not offer serious obstacles to exploratory work. The fact that the Carson Sink receives the drainage of both the Humboldt and the Carson Rivers, each of which drains relatively large areas, as well as the extent of the Quaternary lake, makes this basin comparatively attractive for exploration. The greater area of the Carson Desert and the difficulty of securing accurate information from surface studies as to the probable structure of this basin would render a search for salines almost as difficult as in the Black Rock Desert.

The U. S. Geological Survey put down a bore in the Carson Desert at what was hypothetically assumed to be the axis of the deepest depression in the Quaternary lake basin. The site of the bore is close to the north end of Timber Lake in sec. 30, T. 21 N., R. 30 E. The bore was sunk to a depth of about 985 feet and failed to penetrate either saline beds or brines. The log of the bore to a depth of 320 feet is

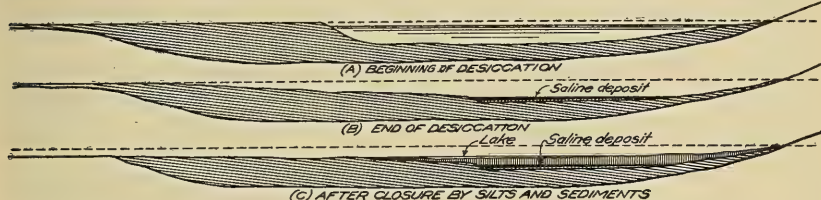


FIG. 8.—Cross sections showing probable conditions existing in Carson Lake at different stages of desiccation.

published in the bulletin noted below.¹ Sand, clay, and quicksand were the principal sediments penetrated to this depth. Artesian water was encountered at a number of different levels. Examination of these waters showed them to be of low saline content. Certain samples showed from 0.10 to 0.22 per cent potassium.² Other water samples showed from traces to 0.1 per cent. At greater depths than that established by the record it is said that no notable quantity of saline material was found. A study of the Carson topographic sheet, together with the information shown by this bore, indicates that the bore was put down in the delta material deposited by the Carson River. That this delta deposit is of great thickness and outside of the area of possible occurrence of saline beds is not an unwarranted conclusion. We would expect sedimentation to be most active at the mouth of the Carson. Examination of older and more recent maps indicates changes in the position of the Carson River where it enters Carson Lake. The delta formed by the Carson during the Quaternary lake period must have been eroded in part and must have supplied the alluvial material of the present delta. The probable changes which took place during the evaporation of Carson Lake in this delta material and in the deeper portions of the basin are represented by figure 8. Three stages are indicated. In the first stage, or the beginning of desiccation, a deep lake is represented, in one end of which is a considerable delta deposit. The finer sediments and silts carried into the lake are represented as a thick bed upon the bottom. As the lake evaporated, erosion began in the former delta deposit and a new delta began to form from the debris of the old. This new delta would be expected to reach out as the lake evaporated and, as it were, push the lake farther and farther down its bed. The end of the desiccation period is represented in the *b* sketch. On the resumption of greater rainfall we would expect silts and sediments to be brought down from the erosion of the remnants of the older delta. Under certain conditions the saline beds would be closed over by this material. The bottom diagram, figure 8, shows the conditions at the end of the third period. An examination of *c* section would indicate that the saline deposits would be removed at some considerable distance from the remnants of the old delta. The flatness of the Carson Desert and its extent, particularly to the east, needs to be seen to be appreciated.

¹Bul. No. 530A, U. S. Geol. Survey, p. 18.

²Probably on total solids.

The shore lines in the bottom of the basin, which appear with great distinctness, indicate the slow recession and evaporation of the waters. Sufficient time is indicated for the development of a structure similar to that shown in sketch *b*. Wind erosion, no doubt, played an important part in the closure of the saline beds. The soft character of the Lahontan sediments and the fact that the prevailing winds are from the west would indicate favorable conditions for æolian action. The east end of the Carson Desert, and particularly that portion along the flanks of the Sweetwater Range, is conspicuous for the large sand dunes which have resulted from the wind action of the present.

The general features involved in the search for the buried salines of the Carson Sink may well be considered. A study of the probable structural relations attending the formation and closure of a saline deposit such as might have taken place in the Carson Sink has shown that the most favorable area is removed from the delta area, either old or new. In the particular case of the Carson Desert a line might be drawn at the present mouth of the Carson and extending southeast and northwest. Southwest of this line is the delta area. Northeast is the area considered as most favorable for the search of a saline deposit. The area between the line established above and the lowest contour—3,900 feet—inclosing the present lake is about 350 square miles. The main deposit of Searles Lake occupies an area having a ratio of 1 to 404, as compared with the area of the whole present basin including the salt deposit. The drainage area of the Carson and Humboldt Rivers is 27,575 square miles. Using the above ratio would give a probable area of saline deposit of 68 square miles. The extent of a saline deposit would be determined by its thickness. Consequently the above area might be larger or smaller. Again, the deposit might be divided, which is not at all unlikely in the present case. The prospecting problem would be to locate by boring an area greater or less than 68 square miles in an area of 350 square miles.

The nature of the saline bed, if it were discovered, might be similar to that in Searles, or the salines might be distributed in a relatively thick bed of æolian sediments. Respecting the probability of potassium little can be said. Gale's discovery in Columbus Marsh opens up possibilities which in my judgment would warrant exploration in this area.

The only other instance of exploration for buried salines is in Railroad Valley, Nev., where a 1,200-foot bore was sunk, but without results. The valley is unlike the Carson Sink in that no large stream discharges into it, and there is no lake of consequence. The results of the bore have been discussed.

SALINES IN PRESENT LAKES.

The composition of the waters of the more important lakes of the basin region are given in Table XV (Appendix). The three most important lakes from the standpoint of concentration and amount of salines are Great Salt, Owens, and Mono Lakes. The computed quantities of the more important salines in these lakes are given in the table which follows:

Quantities of salts in Great Salt, Owens, and Mono Lakes.

Lake.	NaCl.	Na ₂ SO ₄ .	KCl.	Na ₂ CO ₃ .	Na ₂ B ₄ O ₇ .
	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>
Great Salt ¹	400,000,000	30,000,000	.....	.....	.....
Owens ²	20,000,000	22,000,000	2,140,000	22,000,000	.....
Mono ²	86,099,600	47,586,400	10,538,000	92,101,100	945,100

¹ Monograph 1, U. S. Geol. Survey, p. 253.

² 8th Annual Report. Quaternary History of Mono Valley, Cal., pp. 295-296. Potassium sulphate has been recalculated to potassium chloride in the case of Owens Lake.

Salt is separated from the brines of Great Salt Lake and at Owens Lake sodium carbonate and bicarbonate have been separated by solar evaporation and crystallization for a number of years. At Large Soda Lake, Nev., soda was also separated. Outside of this, there has been no other commercial utilization of the waters of the basin lakes. Only two other lakes in the basin approach the three mentioned above in degree of salinity—South and Middle Alkali Lakes, Oreg. (Pl. V, fig. 1.) The saline content of the remaining lakes is of little present importance. No important concentration of potassium salts has taken place in the present lakes, excepting inconsequential cases which have been mentioned before. Later investigations have not supported the earlier estimates of notable concentrations of potash salts in Abert Lake and the Surprise Valley. (Pl. V, fig. 2, and Pl. VI.)

CALCAREOUS DEPOSITS ABOUT THE SHORES.

Tufa deposits have been found about the shore lines of many of the Quaternary lake basins. They are not so conspicuous in Bonneville as at Lahontan or Mono. They have been reported from Searles and Owens Lakes. The origin of this tufa, its composition and mineralogy, have been discussed by Russell and Gilbert,¹ and it is not important that they be repeated here. The significant feature of these deposits is their potassium content. Gilbert quotes analyses from the Fortieth Parallel Survey which show 0.22 per cent potassium. This is significant, as it indicates one way in which potassium compounds separate out from lake waters. The deposits are of no commercial interest. They have been an important means of interpreting the events of the Quaternary history.

POTASH-RICH MINERALS.

Of the soluble potash-rich minerals kalinite and niter are the only two known as mineral species in the basin region. Undoubtedly potassium chloride and sulphate are associated with the bedded salines, but no distinct mineral species has been reported.

The insoluble potash minerals, with the exceptions noted below, are associated with other rock-forming minerals in igneous rocks. Rocks containing notable quantities of potash-rich minerals are inconspicuous. Ransome² reports a leucite basanite from the Bullfrog district, Nevada, but this rock contains a very low percentage of potash.

The occurrence of alunite has been discussed already. Jarosite contains from 6 to 9 per cent potash. This mineral is not uncommon and has been reported from Tonopah, Goldfield, and Bullfrog, Nev. It is associated with quartz and, in the occurrence at Goldfield, it is found in an altered tuff.³ It does not occur in quantity and is of no economic importance. Orthoclase has been reported, but, so far as known, no notable amounts of this mineral are available. Adularia has been reported from Jarbridge, Nev. The analyses show a potash content ranging from 11.84 to 15.12 per cent.⁴ The mineral occurs associated with quartz in veins. With the exception of the alunite deposit noted in a previous section, the possibility of finding workable deposits of potash-rich minerals or rocks is not good.

GYPSUM.

Three types of gypsum deposits are found in the basin region—rock gypsum, gypsite, and lake gypsum. Rock gypsum occurs in Nevada at Mound House, Gerlach, Lovelock, Table Mountain, the Ludwig mine in Mason Valley, and at Arden, Clark County. At Mound House and Lovelock the gypsum is associated with limestone. At Mound House, Gerlach, and the Ludwig mine the surface gypsum passes into anhydrite at depth. Probably in all cases the rock gypsum is associated with rocks of Triassic age.⁵

At Mound House gypsite occurs in thin beds upon a number of low, crescent-shaped terraces which are a part of the alluvial slope between the rock gypsum deposit and the Carson River. It has undoubtedly been derived from the erosion and partial solution of the rock gypsum deposits above. Seepage and surface waters have caused the concentration of the gypsum in beds varying from 2 to 3 feet in thickness. The material is of a pulverulent nature. Analyses taken from several of these beds and at a number of different points are given in the following table:

Analyses of samples from gypsum deposits.

[Samples collected and analyses made by G. J. Young.]

Constituent.	Sample No.—							
	1	2	3	4	5	6	7	8
Gypsum.....	<i>Per cent.</i> 59.79	<i>Per cent.</i> 68.20	<i>Per cent.</i> 79.51	<i>Per cent.</i> 53.94	<i>Per cent.</i> 50.43	<i>Per cent.</i> 82.75	<i>Per cent.</i> 79.81	<i>Per cent.</i> 72.37
Calcium carbonate...	14.01	12.83	8.72	12.58	13.58	6.35	8.82	5.21
Insoluble.....	26.13	8.72	11.78	33.48	35.98	10.80	11.33	22.39

¹ Monograph 1, p. 167, Gilbert; 11th Annual Report, p. 187, Russell; Bul. No. 108, U. S. Geol. Survey, p. 94, I. C. Russell.

² Bul. No. 407, U. S. Geol. Survey, p. 58.

³ Professional Paper No. 66, U. S. Geol. Survey, p. 108.

⁴ Bul. No. 497, U. S. Geol. Survey, p. 52.

⁵ See G. D. Louderback, Bul. No. 223, U. S. Geol. Survey, p. 118.

F. L. Hess¹ describes the occurrence of gypsum in recent lake beds in the Mojave Desert, Cal. The beds occur in a periodic lake in the vicinity of Amboy, Cal. Bristol Lake is the name given to the area. The gypsum occurs in the lake bottom close to the shores of the lake. The bed is of variable thickness and its maximum thickness has not been determined. In one place gypsum was found to a depth of 9.5 feet, the upper layers being more or less mixed with dirt. A brine is reached in the lake bed at a depth varying from 8 to 10 feet. Prospect holes show the deposit to be confined from within one-half to 1 mile of the old shore line. The gypsum is of a granular nature. Hess ascribes the localization of a deposit of this kind as being due to the greater evaporation rate of the lake waters near the shore. Capillarity in the marginal material also undoubtedly has contributed to the local concentration of the gypsum.

Rock gypsum is being mined at Mound House, Arden, and Ludwig. The deposits are of considerable commercial importance. The gypsite deposits at Mound House were worked for a time, but have been idle for some years. They are of doubtful value. The gypsum at Bristol Lake is reported by Hess as being exploited by the Pacific Cement Plaster Co.

CONCLUSION.

Repeated reference has been made to the Stassfurt deposits of Germany in connection with the search for potash salts in the United States. While this has served a useful purpose in stimulating the search for salines, it perhaps has resulted in the opinion that similar deposits might be expected in the Great Basin. Such a view can not now be held. The German deposits are in the Triassic and they, as well as the associated sedimentaries, have been folded and tilted. They represent complete desiccation and more or less secondary action before, during, and after tectonic disturbance. Omitting from present consideration the deposits of the Jurassic and Tertiary, the saliniferous deposits of the Great Basin may be said to represent comparatively recent geologic activity. They are confined to the Quaternary lake and desert basins. The older deposits were formed in earlier periods of desiccation, but desiccation did not reach extreme conditions. The present deposits are in process of formation. Very little disturbance of the Quaternary and recent sedimentaries has taken place. More or less secondary action, such as solution, recrystallization, and movement of brines, is taking place. It may be said that the basin deposits already discovered represent the initial stages of what in time might result in deposits rather remotely similar to Stassfurt, but of much less magnitude.

The influence of regional rocks has been commented upon and the prevalence of volcanics in the Great Basin has caused geologists to turn to this region as a place in which to look for potassium salts. Regional differences, caused by the prevalence of different types of rocks, are manifest in the presence of alkali carbonates and borates in the western part of the Great Basin and the presence of chlorides in the eastern portion where sedimentaries predominate. In the case of potassium, no such marked difference is shown. The potassium content in the saline residue of the water of Great Salt Lake is not much less than that of Mono, Owens, and Pyramid Lakes. Humboldt Lake, North, Middle and South Alkali Lakes, it is true, show a higher content of potassium, but these are relatively unimportant. The resistance to weathering of the potash-rich minerals and the ease with which this element is absorbed and removed from surface and underground waters might well account for the low content of potash in all of the lakes.

With the exception of the crusts and efflorescences about hot springs and in soils, no notably high potassium content has been reported from salines taken from beds. The potassium content in material of this nature ranges from less than 1 to 2 per cent. It is not in the salts which have crystallized out, but in the residual brines or mother liquors that concentration of potassium has taken place, and it is to these that we must look for potassium salts. As desiccation approaches completion, so will the residual brines increase in proportion of potassium. A near approach to complete desiccation would give a brine high in potash. The fortuitous absorption and sealing over of such a brine would protect it from further changes, except those produced by circulating underground waters. It is evident that the above action might occur at different stages of desiccation, and brines varying in degree of potash content would be absorbed and sealed in the same way. Sealing would not necessarily have to be caused by the formation of impervious layers, although this would be more effective than a layer of sand. A layer of sand, subsequently flooded with water, would deplete by diffusion the partially concentrated brine beneath and, in time, a much weaker brine would result. It should be noted that the absorption of saline waters which

¹ Bul. No. 413, U. S. Geol. Survey, p. 125.

have not reached concentration sufficient to produce crystallization of some of the compounds would give little or no concentration of potassium. The absorption of such a solution by desert sands would give a weak and valueless brine. Doubtless further investigation will show many of the variations indicated above.

Two general types in the desiccation phenomena may be distinguished, the Searles type, in which a large, deep lake was evaporated, and the comparatively thick bed of saline material, restricted in area and saturated with residual brine, was formed and a second type, which is best illustrated by Death Valley, in which case was the building up of a mass of muds and silts with interbedded salines, by the repeated formation and desiccation of a shallow lake. To the latter type belong most of the desert, dry lakes, or playas. The line between the two types is not a sharp one.

The possibility of deposits at depth is still not completely disproved. The geological evidence goes to show that several periods of desiccation occurred. Each period might have been characterized by deposits of the kind described above. Such evidence as we have, and it is meager, does not indicate deposits of this nature. The evidence goes to show that the larger Quaternary lakes existed for a long time and desiccation was a feature of their final stages. This would place the period of saline formation at the end rather than at an intermediate time, and would argue for deposits at shallow depths rather than otherwise. On the other hand, the geological evidence is not necessarily complete. The obliteration by erosion of older lake lines than the present ones is not improbable. Only by systematic deep boring could such a question be settled. As the larger Quaternary lake basins are, in almost every instance, occupied by lakes of considerable size and in some instances of considerable depth, the difficulties of such work are apparent.

The question of deep deposits being uncertain, the field becomes narrowed to the deposits which might have resulted from the desiccation periods of the most recent Quaternary lakes. Only in Searles have we surface deposits of this nature. In all other basins, if older deposits than those at present forming exist, they must be sought for at depth. The size of such a deposit would depend upon the area of the drainage basin and the area and depth of the Quaternary lake occupying it. Desert basins showing no signs of former lakes might well be placed in a separate and unimportant class. Such basins can not be said not to have saline beds at depth, but the existence of such beds and their value are doubtful. Upon the criteria stated above I have grouped the desert basins in the following manner:

GROUP I.—*Basins formerly occupied by Quaternary lakes.*

A. Basins in which the Quaternary lake was over 300 feet in depth: (in order of magnitude on the basis of area):		Square miles,
Carson and Humboldt.....	27,575	
Black Rock and Smoky Creek Deserts.....	10,500	
Searles (area includes Owens).....	4,850	
Panamint.....	1,950	
B. Basins in which the Quaternary lake was 300 feet or less in depth:		
Railroad Valley.....	6,340	
Columbus Marsh (including Big Smoky Valley).....	5,225	
Buena Vista (part of Caron and Humboldt).....	4,000	
Dixie Valley.....	2,660	
C. Basins which are now occupied by lakes:		
Bonneville Basin.....	54,000	
Walker, Nev.....	3,850	
Alvord, Oreg.....	3,200	
Pyramid, Nev.....	2,975	
Owens, Cal.....	2,825	
Honey Lake, Cal.....	2,660	
Surprise Valley, Cal.....	2,350	
Catlow, Oreg.....	2,000	
Warner, Oreg.....	2,000	
Abert, Chewaucan, and Summer, Oreg.....	1,500	
Madeline Plains, Cal.....	900	
Long Valley, Nev.....	775	
Mono, Cal.....	770	
Silver, Oreg.....	500	
D. Doubtful basins:		
Diamond Valley, Nev.....		
Danby and Bristol Lakes, Cal.....		
Franklin and Ruby Lakes, Nev.....		

GROUP II.—*Basins in which there are no evidences of Quaternary lakes.*

	Square miles.
A. Death Valley, includes Amargosa drainage and basin.....	23, 160
B. Silver Peak.....	550
Rhodes Marsh.....	540
Teels.....	320

All other basins in which the playa contains notable quantities of brine and in which the brines are close to, or at, the surface.

C. All other desert basins and playas not included in the above groups.

The order given in each main group is the order of relative importance. In each subgroup the order given is the order of areal importance. Groups A and B of each main group are believed to be the most favorable areas for exploration work. Group II is of very much less importance than Group I.

Of the basins enumerated above, Searles is the only one in which the investigation has shown sufficient concentration of potassium salts in the residual brines to be of probable commercial importance. The salines associated with the potassium salts and the possibility of producing several products predict success in the exploitation of this area. The chemical problem of separating the several salines is a difficult one, and upon its solution hinges the success of the enterprise. The presence of brines of moderate concentration is shown in Death Valley and Silver Peak.¹ It is a matter of some doubt whether these brines can be worked. The investigation of the Carson Sink, Railroad Valley, and Columbus Marsh is inconclusive. Until the possibilities of the areas considered most favorable have been exhaustively studied, it is inadvisable to attempt exploration of the other areas.

¹ The potassium in the surface brines of the smooth salt area of Death Valley is equivalent to 1.72 per cent potassium chloride; in the brines from the Survey's bores in Death Valley it is equivalent to 0.94 per cent and in the brines of Silver Peak Marsh 1.50 per cent. But comparatively little concentration would be required in these brines to produce a brine of the same content of potassium chloride as the Searles brine. The Death Valley surface brine would have to be concentrated one-half, the deeper brines one-fourth, and the Silver Peak brine somewhat less than one-half. In Death Valley the summer evaporation rate for a brine is said to be from 24 to 30 inches per month. The cost of evaporating a brine under such conditions would be almost nothing. The amount of brine available for pumping and the practicability of constructing vats upon the smooth salt area would have to be determined by detailed examination and experimentation. In my opinion the experiment of producing potassium salts by evaporating the Death Valley brine is well worth carrying out, presupposing that the detailed examination shows a sufficient quantity of brine.

APPENDIX.

MINERALOGY OF THE SALINES.

A number of minerals have been reported in the salines of the basin. In addition to distinct mineral species mention must be made of the mixtures of chlorides, sulphates, borates, and carbonates which are of common occurrence.

List of minerals.

[Compiled from Dana, Clark, Eakle, and records of Cooperative Laboratory and State Mining Laboratory of the University of Nevada.]

Name.	Chemical symbol.	Name.	Chemical symbol.
Soluble minerals:		Insoluble or almost insoluble minerals:	
Thermonatrite.....	$\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$.	Anhydrite.....	CaSO_4 .
Natron.....	$\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.	Gypsum.....	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.
Trona.....	$\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$.	Celestite.....	SrSO_4 .
Mirabilite.....	$\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$.	Calcite.....	CaCO_3 .
Thenardite.....	Na_2SO_4 .	Dolomite.....	$\text{MgCa}(\text{CO}_3)_2$.
Halite.....	NaCl .	Tychite.....	$2\text{MgCO}_3 \cdot 2\text{Na}_2\text{CO}_3 \cdot \text{Na}_2\text{SO}_4$.
Borax.....	$\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.	Colemanite.....	$\text{Ca}_2\text{B}_6\text{O}_{11} \cdot 5\text{H}_2\text{O}$.
Soda niter.....	NaNO_3 .	Pandermitte (var.).	
Niter.....	KNO_3 .	Ulexite.....	$\text{NaCaB}_5\text{O}_9 \cdot 8\text{H}_2\text{O}$.
Nitrocalcite.....	$\text{Ca}(\text{NO}_3)_2 \cdot n\text{H}_2\text{O}$.	Howlite.....	$\text{H}_2\text{Ca}_2\text{B}_3\text{SiO}_{14}$.
Nitromagnesite.....	$\text{Mg}(\text{NO}_3)_2 \cdot n\text{H}_2\text{O}$.	Boracite (?).....	$\text{Mg}_7\text{Cl}_2\text{B}_{16}\text{O}_{36}$.
Hanksite.....	$\text{Na}_{22}\text{K}(\text{SO}_4)_9(\text{CO}_3)_2\text{Cl}$.	Neocolmanite.....	Same composition as colemanite.
Kalinite.....	$\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$.	Sulphur.....	S .
Partly or slightly soluble minerals:		Pirssonite.....	$\text{Na}_2\text{Ca}(\text{CO}_3)_2 \cdot 2\text{H}_2\text{O}$.
Glauberite.....	$\text{Na}_2\text{SO}_4 \cdot \text{CaSO}_4$.		
Sulphohalite.....	$3\text{Na}_2\text{SO}_4 \cdot 2\text{NaCl}$.		
Gaylussite.....	$\text{Na}_2\text{Ca}(\text{CO}_3)_2 \cdot 5\text{H}_2\text{O}$.		
Northupite.....	$\text{MgCO}_3 \cdot \text{Na}_2\text{CO}_3 \cdot \text{NaCl}$.		

In addition to the above, potassium chloride and sulphate, and magnesium chloride and sulphate, are to be found in mixtures but have not been reported as minerals. Hydrogen sulphide, ammonia, iodine, bromine, and arsenious oxide have been reported in analyses. Marsh gas has been reported from a bore near Fallon, Nev.

Certain temperature observations have been made in connection with the synthetic studies of saline compounds and these have been summarized below:

Temperature controlling formation of saline minerals.

$^{\circ}\text{C}$.	
110.....	Pandermitte formed from solution of sodium and potassium chlorides. ¹
100.....	Anhydrite formed from action of sulphuric acid on calcium carbonate. Tychite and northupite formed at temperature of steam bath. ²
70.....	Colemanite formed from ulexite in salt solution. ¹
34 and above.	Thenardite formed from sodium sulphate solution. ³
34 and below.	Mirabilite formed from sodium sulphate solution. ³
20 to 33.....	Trona, borax, ulexite, gaylussite, natron, gypsum, hanksite, halite, sulphohalite; deposited from solution. Anhydrite forms from saturated salt solution.
10 and above.	Glauberite. ¹

¹ Clarke, Bul. No. 491, Data of Geochemistry, U. S. Geol. Survey, p. 216.

² Am. Jour. of Sci., 4th Series, v. 20, p. 217.

³ The Occurrence of Potassium Salts in the Salines of the United States, Bul. No. 94, Bureau of Soils, U. S. Department of Agriculture.

Soluble minerals are deposited from solution by simple evaporation. The presence of one or more soluble minerals in an evaporating solution would result in the partial separation of a mixture of the several compounds present, and the proportion of each in the "solid phase" would depend upon the solubility and proportion of each originally present. Under certain conditions, as, for instance, the preponderance of one compound, when the solution reached a concentration exceeding the solubility of this compound, it would separate out alone until the residual solution reached a constant condition, when another compound or compounds would separate out of the "constant solution." The evaporation of a solution containing a number of soluble salines might be expected to deposit, in sequence, first a single compound and then always a mixture of compounds, the sequential mixtures varying with the composition of the original solution. Just what mixture would be deposited would depend upon the composition of the "constant solution" formed at the several stages. Turrentine¹ has very fully discussed van't Hoff's work upon the separation of saline compounds from solution, and it is unnecessary to repeat it here.

Experimental data for the interpretation of results which might be expected from the evaporation of saline solutions occurring in the western half of the Great Basin are not complete. Chatard published the results of his work upon the saline solutions of Owens and Mono Lakes, and these have been presented in another place. They indicate, for a system composed of chlorides, sulphates, carbonates, and borates, the initial separation of calcium carbonate and ferric oxide, followed in order by trona and then mixtures of carbonates, chlorides, and sulphates. The last brine contained sodium carbonate, sodium chloride, potassium chloride, sodium borate, and nitrates. Apparent separation of potassium chloride or sodium borate in the first crops of crystals was due to the inclosure of the brine by the separated salts. The nonseparation of potassium and boron compounds was due to the small proportion of these compounds originally present. The carrying of Chatard's experiments several steps further would have undoubtedly resulted in additional crops of crystals, which would have contained potassium and boron compounds.

Instances of the deposition of soluble minerals by evaporation of solutions are, of course, common. Halite, trona, mirabilite, natron, and hanksite are deposited from lake waters. Of the soluble minerals named, with the exception of mirabilite, as far as our present information goes, none would be affected by the climatic temperature range. Mirabilite alters to thenardite at ordinary temperatures and when in solution thenardite is deposited at a temperature of 34° C., or above. This temperature is not uncommon in the Great Basin.

Of the partly soluble and almost insoluble minerals our information concerning temperature conditions of formation is scanty. Most of them are formed by direct precipitation under normal temperature conditions. Pandermite, colemanite, tychite, and northupite would appear to require higher temperatures than would be afforded by the climatic temperature range. The absence of colemanite in most marsh deposits (reported only in Searles Marsh), and its presence in veins and as amygdaloids in basalt, would favor the supposition that this mineral only formed in the presence of heated solutions. Tychite and northupite are comparatively rare, and we might well conclude that some local conditions—such as the presence of a hot spring—favored their formation. The occurrence of howlite in association with colemanite would lead to the supposition that this mineral forms under similar temperature conditions.²

Secondary changes in deposited salines have not been made the subject of special study. Examples of the reduction of sulphates by organic matter and the formation of hydrogen sulphide and sulphur; the reduction of nitrates and the formation of ammonia have been reported. Reactions of this kind are characteristic of the more deeply buried beds. The formation of ulexite in nodules in the marshes would indicate this mineral to be of secondary nature. Anhydrite slowly changes over into gypsum. Mirabilite alters to thenardite. Glauberite alters to calcite (Dana). Ulexite alters to gypsum (Dana).

Minerals typically occurring in veins and veinlets are kalinite, alunite, niter, nitrocalcite, nitromagnesite, colemanite, and howlite. All others occur in playa beds, in crusts and efflorescences. Glauberite has been found associated with thenardite and mirabilite. Sulphohalite has been found implanted on crystals of hanksite (Dana). Hanksite is found with halite, thenardite, glauberite, trona, and borax. It has also been found inclosed in borax crystals (Dana).

¹ Bul. No. 94, Bureau of Soils. The Occurrence of Potassium Salts in the Salines of the United States.

² Bul. Dept. of Geology, University of California, vol. 6, No. 9, p. 187.

TABLES.

TABLE I.—Showing mean annual precipitation.

BASIN REGION—UTAH.

Station.	Altitude.	Mean annual precipitation.	Station.	Altitude.	Mean annual precipitation.
	<i>Feet.</i>	<i>Inches.</i>		<i>Feet.</i>	<i>Inches.</i>
Ibapah.....	7,500	12.37	Alpine.....	4,900	19.28
Frisco.....	7,318	8.21	Toole.....	4,900	16.22
Woodruff.....	6,500	10.01	Blackrock.....	4,872	10.61
Meadowville.....	6,200	18.41	Mount Nebo.....	4,650	10.53
Marysville.....	6,180	12.23	Deseret.....	4,541	8.04
Beaver.....	6,000	12.87	Provo.....	4,532	13.71
Heber.....	5,606	17.64	Logan.....	4,507	15.69
Nanti.....	5,575	12.06	Salt Lake City.....	4,366	16.33
Modena.....	5,479	11.50	Ogden.....	4,310	14.74
Richfield.....	5,350	7.96	Farmington.....	4,267	21.17
Government Creek.....	5,277	14.38	Corinne.....	4,240	12.51
Scipio.....	5,260	15.25	Kelton.....	4,230	6.38
Fillmore.....	5,100	14.72	Coyoto.....	.....	8.21
Minersville.....	5,070	11.54	Garrison.....	.....	6.83
Levan.....	5,010	16.38			
Promontory.....	4,913	8.23	Average.....	.....	12.80

BASIN REGION—NEVADA (AND PORTION OF CALIFORNIA).

Bodie, Cal.....	8,248	14.48	Quinn River Ranch.....	4,850	6.55
Belmont.....	8,000	8.67	Battle Mountain.....	4,843	6.71
Hamilton.....	7,977	16.80	McAfee's Ranch.....	4,835	5.46
Summit, Cal.....	7,017	47.78	Gardnerville.....	4,830	12.12
Potts.....	6,980	7.14	Pailsade.....	4,821	8.69
Austin.....	6,594	11.72	McDermott.....	4,700	11.94
Eureka.....	6,500	13.17	Golconda.....	4,697	5.96
Palmetto.....	6,500	18.53	Beowawe.....	4,695	6.48
Tybo.....	6,500	9.32	Carson.....	4,660	11.01
Lewer's Ranch.....	6,282	26.96	Hawthorne.....	4,569	3.56
Candelaria.....	6,180	4.98	Reno.....	4,497	8.65
Fenelon.....	6,128	9.23	Mill City.....	4,391	4.73
Pioche.....	6,100	11.24	Iron Point.....	4,375	7.45
Tonopah.....	6,090	6.37	Winnemucca.....	4,344	8.65
Clover Valley.....	6,000	15.00	Humboldt.....	4,336	5.32
Ruby Valley.....	6,000	10.71	Fernley.....	4,150	4.62
Toana.....	5,975	8.16	Hot Springs.....	4,072	3.37
Truckee.....	5,818	26.90	Lovelock.....	3,977	3.10
Halleck.....	5,631	8.29	Fallon.....	3,965	4.81
Wells.....	5,628	8.97	Brown.....	3,929	3.83
Boca.....	5,535	20.34	Downeyville.....	3,800	6.47
Crane's Ranch.....	5,350	11.48	Las Vegas.....	2,033	3.57
Elko.....	5,342	8.44	Logan.....	1,700	6.04
Carlin.....	5,232	7.22			
Verdi.....	4,895	15.47	Average.....	.....	10.34

BASIN REGION—CALIFORNIA.

Bishop.....	4,450	5.96	Barstow.....	2,150	3.61
Independence.....	3,907	5.25	Bagdad.....	784	2.98
Lone Pine.....	3,661	5.28	Needles.....	477	4.30
Keeler.....	3,620	3.06			
Mohave.....	2,751	5.00	Average.....	.....	4.43

BASIN REGION—OREGON.

Lakeview.....	4,825	17.85	Klamath Agency.....	4,200	21.47
Silver Lake.....	4,700	10.40	Burns.....	4,157	10.87
Warner.....	4,700	14.80	Riverside.....	3,000	9.76
Paisley.....	4,500	10.90			
Klamath Falls.....	4,250	12.54	Average.....	.....	13.59
Happy Valley.....	4,200	13.73			

TABLE II.—Mean annual precipitation at certain stations in the Great Basin, arranged according to latitude.

North latitude 42° to 43°.			North latitude 39° to 40°.			North latitude 37° to 38°.			North latitude 35° to 37°.		
Station.	Eleva- tion.	Mean annual precipi- tation.	Station.	Eleva- tion.	Mean annual precipi- tation.	Station.	Eleva- tion.	Mean annual precipi- tation.	Station.	Eleva- tion.	Mean annual precipi- tation.
Grants Pass.....	<i>Feet.</i> 956	<i>Inches.</i> 32.20	Sacramento.....	<i>Feet.</i> 71	<i>Inches.</i> 19.50	Merced Falls.....	<i>Feet.</i> 173	<i>Inches.</i> 23.21	Independence.....	<i>Feet.</i> 3,907	<i>Inches.</i> 6.25
Ashland.....	1,940	20.18	Rocklin.....	249	28.45	Summertale.....	2,270	56.45	Lone Pine.....	3,661	5.28
Klamath Falls.....	4,250	12.54	Auburn.....	1,363	34.33	Bishop.....	4,450	5.96	Keeler.....	3,620	3.06
Lakeview.....	4,825	17.18	Colfax.....	2,421	49.01	McAfee's Ranch.....	4,835	5.46	Mohave.....	2,751	5.00
Warner.....	4,700	14.80	Gold Run.....	3,222	54.49	Palmetto.....	6,500	18.53	Barstow.....	2,150	3.61
Happy Valley.....	4,200	13.73	Blue Canyon.....	4,695	72.82	Pioche.....	6,100	11.24	Bagdad.....	2,150	2.98
			Cisco.....	5,939	51.96	St. George.....	2,880	8.66	Needles.....	477	4.30
			Summit.....	7,017	48.00	Kanab.....	4,925	14.02			
			Truckee.....	5,820	27.65	Aneth.....	4,800	7.16			
			Reno.....	5,531	20.47						
			Booe.....	4,497	8.65						
			Wadsworth.....	4,084	4.59						
			Fallon.....	3,985	4.81						
			Austin.....	6,594	11.72						
			Eureka.....	6,500	13.17						
			Ely.....	6,421	12.24						
			Garrison.....	4,850	6.83						
			Deseret.....	4,541	8.04						
			Scipio.....	5,260	18.25						
			Castle Dale.....	5,500	8.52						
			Green River.....	4,080	6.38						
			Cisco.....	4,447	5.94						

NOTE.—Weather stations are arranged from west to east with exception of stations in north latitude 35° to 37°. Stations below horizontal lines are in Great Basin and stations above these lines are on contiguous watershed. Stations in north latitude 35° to 37° are in Great Basin, with exception of Needles.

TABLE III.—Statistics of temperature.

	Mean temper- ature.	Mean maxi- mum. ¹	Mean mini- mum. ²	Range maxi- mum to mini- mum.	Mean relative humid- ity.
	° F.	° F.	° F.	° F.	° F.
Western Utah.....	47.4	103.6	-18.2	121.8	52
Nevada.....	47.2	105.8	-17.4	113.2	51.3
Oregon.....	46.8	106.1	-22	128.1	³ 61
California.....	63.8	112.5	10	102.5	⁴ 36

¹ Highest annual temperature of each station.

² Lowest annual temperature of each station.

³ Baker City, Oreg.

⁴ Independence, Cal.

TABLE IV.—Proportional area of mountains, outwash slopes, silt, playa, and water in the Great Basin region.

	Sierra- ville, 1,344 square miles.	Reno, 972 square miles.	Wads- worth, 1,344 square miles.	Carson, 3,780 square miles.	Amar- gosa, 8,307 square miles.	Owens Valley, ¹ 3,300 square miles.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Mountains.....	75.4	76	61.4	41.3	55.3	35
Outwash slopes.....				13.7	24.5	46
Silt.....	23.7	18.2	32.4	35.5	18.2	14
Playa.....		.6	.4	5.1	1.7	5
Water.....	.8	5.2	5.6	4.3	0	

¹ Water-Supply Paper No. 294, U. S. Geol. Survey.

TABLE V.—Run-off of the basin region.¹

River.	Drainage area.	Mean an- nual run- off.	Run-off per square mile.	Depth on drainage area.	Length of record. ¹
	Sq. miles.	Second-feet.	Second-feet.	Inches.	Years.
Western Utah:					
Weber River.....		586			2
Bear River.....	6,000	1,860	0.308	4.19	9
Logan River.....	218	339	1.56	21.18	6
Spanish Fork.....	670	157	.234	3.18	4
Sevier River.....	3,990	208	.052	.70	5
Provo River.....	640	433	.676	9.16	6
Nevada:					
Carson.....	988	454	.461	6.25	6
Truckee.....	1,520	1,030	.677	9.18	6
East Fork Walker.....	1,100	213	.193	2.63	3
Humboldt at Oreana.....	13,800	261	.019	.25	7
Humboldt at Palisade.....	5,010	448	.089	1.23	4
California:					
Owens River.....		281			
Mojave River at Victorville.....	400	78.1	.195	2.65	5
Susan River at Susanville.....	256	151.9	.591		2

¹ Water-Supply Papers, Great Basin region.

TABLE VI.—*Run-off of the basin region.*

TRUCKEE.

Year.	Tahoe (519 square miles).		State line (955 square miles).		Vista (1,519 square miles).		Derby (1,740 square miles).		Pyramid (2,130 square miles).	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
1903.....	<i>Sec.-ft.</i> 205	<i>Sec.-ft.</i> 0.40	<i>Sec.-ft.</i> 753	<i>Sec.-ft.</i> 0.79	<i>Sec.-ft.</i> 786	<i>Sec.-ft.</i> 0.52	<i>Sec.-ft.</i> 626	<i>Sec.-ft.</i> 0.892	<i>Sec.-ft.</i> 859	<i>Sec.-ft.</i> 0.40
1906.....	589	1.14	1,420	1.48	1,610	1.06	.....	.....	.....	.....
1908.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1909.....	488	.92	1,530	1.60	.....	.....	1,550	0.892	.....	.....

HUMBOLDT.

Year.	Elko (1,150 square miles).		Golconda (10,800 square miles).		Oreana (13,800 square miles).	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
1903.....	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>
1906.....	210	0.183	171	0.0158	121	0.009
1907.....	248	.....	373	.034	303	.022
1908.....	103	.....	998	.....	720	.....
1909.....	.....	.....	239	.....	164	.....
.....	.....	.....	235	.03	287	.021

WALKER.

Year.	Coleville (306 square miles).		Yerington (1,100 square miles).		Wabuska (2,420 square miles).	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
1903.....	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>
1906.....	582	1.90	322	0.293	170	0.0704
1907.....	.....	.....	390	.....	.....	.....

CARSON.

Year.	Woodfords (70 square miles).		Empire (988 square miles).		Hazen.	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
1903.....	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>
1906.....	231	3.30	429	0.43	.....	.....
1908.....	.....	.....	798	.807	.....	.....
1909.....	.....	.....	212	.....	.....	.....
.....	.....	.....	678	.686	645	.....

TABLE VII.—*Run-off in the Oregon Lake region.* ¹

	Area of watershed.	Mean flow.	Flow per square mile.
	<i>Sq. miles.</i>	<i>Sec.-feet.</i>	<i>Sec.-feet.</i>
Matheur Lake.....	865	364	0.37
Harney Lake, Silver Creek (Riley).....	.....	116	.....
Silver Lake Basin.....	221	55.2	.25
Abert Lake Basin.....	.....	189	.694

¹ Water-Supply Paper No. 212, U. S. Geol. Survey.

TABLE VIII.—List of lakes, with elevations and drainage area of the basins.

Lake.	Basin area.	Lake area.	Ratio basin to lake.	Elevation.	Depth.
	<i>Sq. miles.</i>	<i>Sq. miles.</i>		<i>Feet.</i>	
Great Salt Lake (including Utah and Sevier Lake).	52,000	2,498	20.8	4,200	49 feet average.
Franklin.....	1 1,200	105	11.4	5,950	361 deep-est. 87 deepest.
Ruby.....					
Eagle.....					
Pyramid.....					
Winnemucca.....	1 2,975	310	9.6	3,880	3,875
Humboldt.....					3,929
North Carson.....	1 27,575	195	141.4	3,900	Variable.
South Carson.....					4 feet, very shallow.
Walker.....	1 3,850	118	32.6	4,083	113 feet average.
Mono.....	1 770	85.5	9.0	6,426	61.5 average.
Tahoe.....	519	111	4.6	6,225	1,635 deep-est.
Owens.....	2 3,300	100	33	3,569	40 average.
Honey.....	1 2,660	111.6	23.8	3,949	18 inches.
Eagle.....					
Malheur.....	700	125.6	5.5	4,088	10 feet.
Harney.....					
Alvord.....	1 3,200	4.9	653	4,200	Very shallow.
Silver.....	500	15	33.3	4,340	
Warner.....	2,000	81	24.6	4,600	
Abert.....	900	60	15	4,400	
Summer.....	550	60	9.1	4,300	None exceed 25 feet.
Goose.....	1 065	190	5.6	4,800	
Surprise Valley.....	1 2,350	137	17.1	4,640	

Square miles.

Total lake surface.....	4,196
Basin area.....	210,000
Ratio.....	50 to 1

1 Free's table of basin areas.

2 Water Supply Paper No. 294, U. S. Geol. Survey.

TABLE IX.—Distribution of different rocks in Great Basin region.

Map V, Clarence King, fortieth parallel (17,612 square miles).				Truckee folio (910 square miles).			
	<i>Square miles.</i>		<i>Per cent.</i>		<i>Square miles.</i>		<i>Per cent.</i>
Quartz.....	1,512.9	Alluvial and sediment.....	67.0	Granodiorite.....	180	Granodiorite and rhyolite.....	22
Porphyry.....				Diabase.....	18	Basalt.....	45.1
Granite.....				Porphyry.....		Andesite.....	
Diorite.....				Augite.....		Diabase.....	
Diabase.....	103.9	Andesite.....	14.2	Porphyry.....	6	Metamorphic.....	6.15
Syenite.....				Gabbro.....		Sediment.....	
Trachyte.....	336.6	Rhyolite.....	18.8	Rhyolite.....	20	Water.....	12.5
Andesite.....				Andesite.....	332		
Prophyllite.....	1,810.0	Granite.....		Basalt.....	54		
Rhyolite.....				Slate.....	4		
Basalt.....	2,005.8			Chert.....			
Carboniferous and Archean.....				Quartzite.....			
Triassic.....	561.0			Metamorphic.....			
Tertiary, Humboldt and Truckee.....				Juratrias.....	52		
Quaternary and Recent.....							Shist slate.....
Lake.....				Neocene lake beds.....	5		
					Pleistocene.....	125	
				Water.....	114		

Maps IV and V, King (35,200 square miles):

	Per cent.
Granite.....	10
Rhyolite and trachyte.....	23
Basalt and andesite.....	14
Alluvial and sediment.....	53
Southwestern Nevada and eastern California (8,685 square miles):	
Alluvial.....	54.9
Limestone.....	12.1
Andesites and basalts.....	11.5
Rhyolites and granites.....	21.5

TABLE X.—Composition of rocks of basin region.¹

Constituent.	Granite (av. of 113 analyses).	Rhyolite (av. of 103 analyses).	Andesite (av. of 131 analyses).	Dacite (av. of 44 analyses).	Diorite (av. of 85 analyses).	Diorite (av. of 19 analyses).	Basalt (av. of 110 analyses).	Sandstone (av. of 55 analyses).	Limestone (av. of 29 analyses).	Shales (av. of 16 analyses).
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
SiO ₂	66.64	71.55	61.29	65.31	58.84	52.04	51.29	70.55	8.82	54.32
Al ₂ O ₃	14.76	13.90	15.16	15.37	16.06	15.89	15.65	5.80	.89	14.54
Fe ₂ O ₃	1.62	1.20	2.71	2.45	1.97	2.48	3.10	1.06		2.23
FeO.....	1.72	.94	2.86	1.13	3.79	6.84	5.98	2.53	1.01	2.81
MgO.....	1.51	.60	2.99	1.34	3.93	5.95	8.37	1.16	3.58	3.18
CaO.....	2.74	1.56	4.84	3.35	6.27	8.43	8.78	5.33	44.35	4.47
Na ₂ O.....	3.48	3.23	3.30	3.55	3.62	3.20	2.81	1.82		1.65
K ₂ O.....	4.04	4.17	2.93	2.85	2.17	.98	1.26	1.32	.51	2.11
H ₂ O—.....	.38	.52	.63	1.18	.25	.47	.74			1.74
H ₂ O+.....	1.11	1.71	1.42	2.29	1.31	2.17	1.78	2.96	1.17	3.44
TiO ₂	.42	.30	.56	.53	.67	1.06	1.01	.39		.62
ZrO ₂	.03	.03	.02	.01	.01	.00	.01			
P ₂ O ₅	.16	.13	.26	.15	.22	.23	.37	.17	.13	.17
BaO.....	.12	.09	.15	.09	.08	.16	.08			.08
SrO.....	.04	.03	.05	.04	.03	.01	.04			
MnO.....	.05	.04	.09	.05	.08	.09	.11		1.14	.37
S.....	.74		.07	.02	.16		.08			
Cl.....	.03		.08	.18	.03		.05			
F.....	.02			Tr.						
CO ₂	.32		.56	.07	.51		.49	6.74	38.40	7.93
Li ₂ O.....	Tr.		Tr.	.04						
SO ₃	.07		.03	(?)				.17		.34
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

¹ Compiled from: Vol. I, Fortieth Parallel Survey, Bul. No. 419, U. S. Geol. Survey; Monographs I and XI, U. S. Geol. Survey; Bul. No. 491, Data of Geol. Chemistry, U. S. Geol. Survey.

TABLE XI.—*Analyses of well and spring waters.*

[Parts per 1,000,000. Analyses by S. C. Dismore.]

Reference No.	Locality.	Remarks.	Total solids.	SiO ₂ .	FeO ₃ and Al ₂ O ₃ .	CaO.	MgO.	SO ₄ .	K ₂ O.	Na ₂ O.	Cl.	Free ammonia.	Albuminoid ammonia.	HCO ₃ .	H ₂ SO ₄ .
Dismore:															
1243	Battle Mountain.	Well.	4,422.2	53.4	16.1	60.3	11.7	39.1	17.8	1,858.0	490				
1258	Yerington.	Spring.	872.257	101.2	6.1	68.0	.467	513.5	17.23	114.49	51.0	0.194	0.076		
1257	Moana.	Well.	424.554	81.2	2.2	31.3	1.6	211.05	17.6	50.18	29.0	.004	.020		
1260	Mount Peavine.	Spring.	1,200.778	38.4	4.0	283.1	2.26	649.50	Tr.	17.42	6.0	.056	.042		
1261	Freys.	Well.	1,088.636	120.3	5.9	48.5	1.08	445.8	2.21	408.7	56.0	.136	.01		
1262	Sparks.	do.	1,339.609	104.7	32.2	36.1	1.709	753.4	16.7	363.8	41.0				
1265	Reno.	Artesian well.	157.72	54.5	4.3	28.7	6.32	13.02	10.28	37.60	3.0		.14		
1270	Tonopah.	Water supply.	5,789.905	42.0	268.8	833.2	1,151.38	2,674.37	44.05	889.15	77.0	1.24			
1271	Goldfield.	Well water.	642.70	53.2	10.8	34.4	5.84	97.50	31.01	361.95	48.0				
1272	do.	do.	602.37	54.6	12.8	27.0	5.14	91.70	33.33	323.80	54.0	.024	.03		
1273	do.	Water supply.	822.364	54.4	4.4	146.4	28.20	145.5	12.15	228.11	60.00	Tr.	.027		
1274	do.	do.	347.527	34.6	3.5	55.0	1.10	47.3	16.95	127.75	36.00				
1280	Reno.	Well.	3,221.91	33.6	11.10	541.2	119.3	1,106.74	14.01	1,359.96	119.50	1.10	Excessive.		44.68
1285	Fallon.	Well water.	762.54	67.1	Tr.	7.0	None.		24.64	571.62	180.00	.120	.045	184.71	
1302	Rawhide.	Crystal Wells water supply.	2,663.555	58.1	4.8	33.2	2.17	333.94	9.73	1,855.99	180.00				
1302	do.	Spring 0.25 mile from Crystal Wells.	2,183.65	70.2	2.4	56.0	2.61	375.92	9.74	1,293.46	191.50			181.68	
1302	do.	Crystal Rock water.	2,727.46	62.2	3.8	35.4	3.33	331.68	11.22	1,932.87	177.40			169.56	
1302	do.	White Rock well water.	2,620.40	68.10	3.2	151.4	46.39	342.24	10.71	1,744.16	128.00			130.20	
1319	Sparks.	Spring.	849.02	95.0	Tr.	31.9	8.69	4.28	48.90	625.25	35.00				
1328	Fallon.	Well.	1,108.17	49.0	6.0	5.54	6.08	3.97	22.06	846.52	169.0				
1331	Rawhide.	Town supply.	1,014.80	37.1	8.25	65.25	10.87	331.41	26.92	369.66	165.34				
1332	Dixie.	Well.	1,608.69	24.9	8.50	393.35	77.87	640.53	13.67	232.37	217.00				
1334	Madeline Valley.	do.	452.99	57.50	5.50	92.25	59.70	19.51	15.85	100.59	102.50				
1342	Elko.	do.	489.73	44.2	2.7	76.8	16.27	165.10	1.5	127.89	49.50				
1344	Pinnas Junction.	Spring.	111.90	32.4	Tr.	33.6	17.6	Tr.		20.8	6.0			225.55	
1350	Reno.	Well.	413.74	32.4						12.50					
1351	Goldfield.	do.	456.62	43.7						76.00					
1350	Hawthorne.	do.	825.41	52.1	4.5	198.0	18.81	190.87	25.44	323.19	12.50				

TABLE XII.—*Analyses of waters from Amargosa Valley.*

[Parts per 100,000. Analyses by J. A. Cullen.]

No. of sample.	Total solids.	Ca.	Mg.	K.	Na.	Cl.	SO ₄ .	CO ₃ .	HCO ₃ .
237.....	105.6	6.9	6.0	5.8	10.4	8.5	27.9	1.2	22.0
238.....	1,692.2	Tr.	.7	44.8	534.4	285.0	544.3	96.0	155.6
284.....	101.6	6.7	3.0	4.3	18.3	17.0	30.7	1.12	20.7
295.....	49.8	10.2	10.8	12.8	132.1	101.3	160.8	4.8	65.9
296.....	93.2	5.1	3.3	3.9	17.0	8.5	30.0	2.4	25.6

237. Water Willow Creek at railroad bridge south of Morrison's.

238. Water Amargosa River, same locality.

284. Shoshone, Cal. Water from warm spring.

295. Well at Fairbank's house, Shoshone.

296. Water spring in railroad cut south of Tecopa, Cal.

TABLE XIII.—*Analyses of water from Furnace Creek and Death Valley.*

[Parts per 100,000. Analyses by J. A. Cullen.]

No. of sample.	Total solids.	Ca.	Mg.	K.	Na.	SO ₄ .	Cl.	CO ₃ .	HCO ₃ .
305.....	64.8	2.4	1.4	1.0	14.5	14.2	10.6	2.4	14.6
307.....	20,360.0	175.0	50.3	152.7	7,500.0	874.0	11,525.0	Tr.	11.0
325.....	490.4	71.4	37.0	5.6	75.6	173.0	147.7	Tr.	17.8
348.....	65.2	4.8	3.0	1.5	7.7	19.2	4.9	Tr.	20.0
349.....	1,141.6	3.6	3.3	9.0	321.1	646.0	29.6	Tr.	19.5

305. Slough at first crossing, road from Furnace Creek to Bennett's Well. Water from surface.

307. Water from hole 18 inches deep 1 mile north of sink (saline pond northeast of Bennett's Well).

325. Water from main water hole at Bennett's Well.

348. Water from Texas Spring, Furnace Creek Ranch.

349. Water from well in Furnace Creek Canyon, 13.5 miles east of Furnace Creek Ranch.

NOTE.—A trace of borax is found in all samples.

TABLE XIV.—*Analyses of soluble salts contained in soils.*

Location and No. of sample.	Total soluble salts.	Percentage of total soluble salts.									
		Ca.	Mg.	Na.	K.	SO ₄ .	Cl.	HCO ₃ .	CO ₃ .	NO ₃ .	PO ₄ .
Fallon, Nev., alkali soil: ¹	<i>Per ct.</i>										
Crust No. 9.....	4.10	0.88	Tr.	30.66	1.51	56.98	5.52	4.45	0.35	.....	.....
First foot, No. 10.....	3.57	.78	Tr.	31.20	1.62	49.72	10.64	6.09	.35	.....	.....
Second foot, No. 11.....	3.33	.66	Tr.	30.85	1.62	51.44	8.07	7.36	.....	.....	.....
Third foot, No. 12.....	1.70	Tr.	Tr.	29.76	3.65	41.65	8.23	15.65	1.06	.....	.....
Fourth foot, No. 13.....	.93	Tr.	Tr.	27.68	6.22	38.85	9.01	18.24	.....	.....	.....
Fifth foot, No. 14.....	.78	Tr.	Tr.	28.73	4.61	37.18	10.00	19.48	.....	.....	.....
Average.....	2.40	.38	Tr.	29.81	3.20	45.97	8.58	11.88	.23	.....	.....
Fallon soil.....	11.34	.76	0.04	32.36	.30	56.23	9.53	.76	.02	.....	.....
	.89			31.70	2.10	34.08	12.24	16.71	3.16	.....	.....
	1.18			32.43	1.27	42.82	12.76	10.22	.50	.....	.....
	1.18	.18		31.83	1.13	44.07	10.27	11.96	.56	.....	.....
	1.41			32.04	1.07	48.55	8.05	9.55	.74	.....	.....
	1.81	.94		31.42	1.28	54.73	8.33	3.30	.....	.....	.....
	1.54	1.80		27.47	5.05	53.20	8.51	3.97	.....	.....	.....
	.24			32.22	3.77	25.94	10.46	15.06	.....	.....	.....
	1.01			27.74	7.54	37.26	13.56	10.45	12.55	.....	.....
	1.60			28.28	6.46	45.95	10.27	6.06	.97	2.48	Tr.
	.44			31.30	2.12	15.38	6.63	39.79	4.78	2.08	Tr.
	.51			33.70	2.01	19.64	9.38	19.20	16.07	.....	.....
	1.94			30.73	4.31	35.11	12.41	12.88	4.56	.....	.....
	.66			29.85	3.58	32.08	8.71	22.71	3.07	.....	.....
	1.65			32.23	1.84	40.42	10.09	14.95	1.47	Tr.	.....
	1.80	.66		30.87	1.50	50.20	8.85	7.53	8.39	.....	Tr.
	.49			29.84	3.10	18.28	4.05	36.04	8.59	.....	Tr.
	.80			30.24	2.43	38.95	5.99	20.68	1.71	.....	Tr.

¹ Records of Bureau of Soils.

TABLE XIV.—Analyses of soluble salts contained in soils—Continued.

Location and No. of sample.	Total soluble salts.	Percentage of total soluble salts.									
		Ca.	Mg.	Na.	K.	SO ₄ .	Cl.	HCO ₃ .	CO ₃ .	NO ₃ .	PO ₄ .
Fallon soil.....	<i>Per ct.</i> 3.11 .63 1.08 1.76	0.53 0.38	 0.38	31.92 30.98 32.73 33.06	1.18 3.08 2.15 1.03	52.59 26.08 30.47 39.91	10.30 16.85 21.68 19.41	3.48 20.84 11.69 5.45	 2.17 1.29 .77	..... ..... ..... .....	Tr. Tr. Tr. Tr.
Average.....	1.23	.2	.68	31.1	2.60	38.27	10.83	13.82	2.90	.....	.....
Swan Track, Utah: ¹											
No. 7246.....	2.46	.81	.48	31.61	3.64	19.56	36.66	4.39	2.85	.....	.....
No. 7247.....	2.28	1.05	.61	33.26	2.80	17.06	39.40	2.76	3.06	.....	.....
No. 7250.....	.43	3.23	3.23	21.29	5.55	20.39	13.43	22.23	10.65	.....	.....
No. 7254.....	2.05	.68	.58	33.59	2.72	16.27	40.42	3.50	2.24	.....	.....
No. 7257.....	1.86	1.07	.32	32.12	3.76	17.40	37.71	6.44	1.18	.....	.....
No. 7260.....	.56	.71	.71	29.14	5.76	8.63	25.19	21.59	8.27	.....	.....
No. 7262.....	.65	.92	.92	27.69	6.46	14.16	22.46	20.32	7.07	.....	.....
No. 7269.....	2.24	10.72	1.43	18.40	3.30	27.86	26.51	10.80	.98	.....	.....
No. 7275.....	1.35	6.23	.89	23.14	2.22	20.18	13.50	28.65	5.19	.....	.....
No. 7279.....	2.70	.21	.21	34.41	2.62	20.31	38.46	2.47	1.31	.....	.....
No. 7271.....	2.04	8.32	.48	22.53	2.64	26.36	22.04	15.38	2.25	.....	.....
No. 1000a.....	.45	7.96	3.54	14.16	6.63	29.65	12.39	22.13	3.54	.....	.....
No. 1001a.....	.56	2.48	2.12	23.05	5.32	30.50	17.38	19.15	.....	.....	.....
No. 1002a.....	.80	1.49	1.49	26.98	3.71	26.73	21.78	17.82	.....	.....	.....
No. 1003a.....	.80	1.21	1.21	27.18	4.06	24.96	21.30	20.08	.....	.....	.....
Bear River Valley, Utah: ¹											
No. 11456.....	.41	7.84	2.45	17.16	3.92	12.26	22.54	33.83	.....	.....	.....
Utah:											
No. 13955.....	.43	5.07	6.46	13.37	5.53	10.14	25.80	33.63	.....	.....	.....
No. 13706.....	.68	4.67	4.67	17.78	7.58	6.70	41.10	17.50	.....	.....	.....
No. 13705.....	14.9	9.48	2.65	23.74	.70	6.05	56.74	.64	.....	Tr.	Tr.
No. 1130a.....	.36	11.66	5.56	9.44	6.67	Tr.	41.67	25.00	.....	.....	.....
Elsmore, Utah, ¹ Redfield clay, No. 4729.....	1.72	4.42	1.28	24.65	3.37	44.42	15.58	5.23	1.05	.....	.....
Salt Lake City, ¹ soil No. 1061a.....	2.10	Tr.	Tr.	35.38	2.09	14.04	42.79	5.70	.....	.....	.....
Cornine, Utah, ¹ No. 1129a.....	.68	8.14	4.07	17.72	4.07	10.75	43.03	12.22	.....	.....	.....
Salt Lake City, ¹ soil.....	1.23	1.14	Tr.	34.37	2.51	12.31	46.27	3.40	.....	.....	.....
Silver Lake, Oreg., ¹ No. 1059a.....	1.3	.....	.....	24.23	12.56	29.84	14.47	16.54	2.36	.....	.....
Average.....	1.8	3.98	1.81	24.65	4.40	18.66	29.54	14.8	2.08	.....	.....
Harney County, Oreg., ² soils:											
0-1 foot.....	.566	5.05	1.30	.....	25.44	10.67	21.2	17.6	.84	.....	.....
1-2 feet.....	1.049	.27	.....	.....	16.8	4.14	52.4	12.3	2.05	.....	.....
2-3 feet.....	.734	.69	.....	.....	50.00	13.1	19.75	8.44	8.03	.....	.....
3-4 feet.....	.662	.45	.....	.....	45.3	4.23	18.1	15.1	16.7	.....	.....
4-5 feet.....	.938	8.20	.32	.....	27.8	7.14	10.3	2.53	13.8	.....	.....
5-6 feet.....	.864	.....	.....	.....	32.6	5.55	9.72	12.7	9.23	.....	.....
2 miles north of Lawen: ²											
0-1 foot.....	.202	7.42	.....	.....	27.2	27.2	4.95	28.2	.....	.....	.....
1-2 feet.....	.126	19.0	3.97	.....	23.0	8.73	4.76	31.7	.....	.....	.....
2-3 feet.....	.114	26.3	4.38	.....	23.6	8.77	5.26	31.5	.....	.....	.....
3-4 feet.....	.140	12.8	4.28	.....	20.7	7.14	7.14	29.2	.....	.....	.....
4-5 feet.....	.128	13.2	3.90	.....	26.6	8.59	6.25	29.6	.....	.....	.....
5-6 feet.....	.194	8.24	.....	.....	28.4	8.76	10.3	29.3	.....	.....	.....
Lake County, Oreg., ³ soils:											
1. Thousand Spring Valley.....	.....	.....	.....	33.81	.....	35.62	16.21	14.26	1.00	.....	.....
2. 3 miles west Christmas Lake.....	.....	.....	.....	33.00	.....	39.13	6.37	26.75	.....	.....	.....
3. ½ mile south Christmas Lake.....	.....	.....	.....	34.12	.....	48.15	15.93	1.80	.....	.....	.....
4. Well No. 21.....	.....	.....	.....	32.49	.....	27.84	7.12	38.44	.....	.....	.....
5. North end of sink of Peter Creek.....	.....	.....	.....	31.32	.....	26.29	10.08	32.27	.....	.....	.....
6. 1 mile south of Fos-sil Lake.....	.....	.....	.....	33.09	.....	57.16	7.38	23.6	.....	.....	.....
7. ¼ mile east of Cliff post office.....	.....	.....	.....	19.61	.....	.....	6.72	40.34	.....	.....	.....
8. Center of north alkali flat.....	.....	.....	.....	20.14	.....	.....	15.13	27.23	.....	.....	.....
9. Western arm of alkali basin.....	.....	.....	.....	55.62	.....	.....	20.17	24.20	.....	.....	.....

¹ Records of Bureau of Soils.

² Water-Supply Paper No. 231, p. 53.

³ Water-Supply Paper No. 220, p. 72.

TABLE XV.—Analyses of river and lake waters of the Great Basin region.

Rivers and lakes.	Cl.	SO ₄ .	CO ₃ .	PO ₄ .	NO ₃ .	B ₄ O ₇ .	Na.	K.	Ca.	Mg.	Al ₂ O ₃ .		Fe ₂ O ₃ .		SiO ₂ .	Solids on evaporation.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Parts per 100,000.
Rivers:																
Truckee.....	7.59	12.87	33.30				17.26		11.02	3.49			14.47			15.3
Walker.....	7.50	16.14	30.34				18.07		12.96	2.21			12.78			18.0
City Creek.....	5.38	2.87	52.57				3.74		24.19	7.15		.41			3.69	24.3
Humboldt.....	2.19	13.92	39.55				13.63	2.92	14.28	3.62		.38			9.51	36.1
Ogden.....	23.21	5.65	33.68				11.31	4.16	16.05	5.94						44.4
Weber.....	13.73	9.25	40.00				8.37	4.19	18.19	6.27						45.5
Bear.....	32.36	8.16	21.53						10.12	4.76		2.53				63.7
Jordan.....	34.76	30.68	Tr.				23.04		10.26	1.26						109.0
Lakes:																
Tahoe.....	3.18	7.47	38.73				10.10	4.56	12.86	4.15					18.95	7.3
Humboldt.....	31.82	3.27	21.57				29.97	6.54	1.35	1.88					3.53	92.9
Utah.....	26.87	30.14	8.48	.07			18.34	1.75	5.34	6.85					2.23	125.4
Tulare.....	17.38	16.91	26.55				33.51	1.82	1.50	1.78					.55	136.0
Walker.....	23.77	21.29	17.34				34.83		.90	1.56					.31	250.0
Pyramid.....	41.04	5.25	14.28				33.84	2.11	.25	2.28					.95	348.6
Winnemucca.....	47.83	3.76	7.93				36.68	1.94	.55	.49					.77	360.2
Tulare.....	20.26	20.77	19.55				35.79	2.44	.28	.26					.65	491.0
Harney.....	27.60	7.67	25.87				35.78	1.91		.07					.28	1,047.7
Black.....	7.68	13.24	37.73	Tr.			39.05	2.03							.27	1,850.0
Abert.....	36.04	1.90	20.67				39.93	1.84	.04	.10		Tr.	Tr.		.62	3,917.2
Mono.....	23.34	12.86	23.42				37.33	1.45	.02	.01		.04	.02		.14	5,117.0
Owens.....	25.67	9.95	23.51				32.83	2.18	.12	3.01			.02		.29	7,270.0
Savier.....	52.66	10.88					33.33		.22							8,640.0
(?).....	36.51	10.36	13.78				36.63	2.01	.22						.24	11,370.0
Large Soda.....	55.69	6.62					32.93	1.70	1.05	2.10		.01				23,036.0
Great Salt.....	24.82	9.93	24.55	.11	.45	.14	38.12	1.62	.02	.01					.14	21,370.0
Owens.....	25.39	7.62	26.06	.27	Tr.	Tr.	37.42	1.74	1.47	.03						1,590.0
Summer.....	13.96	17.70	27.79	Tr.	Tr.	Tr.	26.19	1.77	2.16	.43						600.0
Fossil.....	34.84	5.62	18.73	Tr.	Tr.	Tr.	37.48	1.60	1.22							2,010.0
Christmas.....	17.36	13.29	28.78	Tr.	Tr.	Tr.	32.60	5.83	2.04	1.33						470.0
North Alkali.....	26.35	10.61	21.49	.17	Tr.	Tr.	36.51	4.32	.11	.03						9,510.0
Middle Alkali.....	12.60	33.12	13.22	.28	Tr.	Tr.	34.12	3.72	.08							14,610.0
South Alkali.....	42.84	2.73	13.56	.23	Tr.	Tr.	35.64	1.66	.08	.11						3,690.0

NOTE.—Analyses from Bul. No. 491, U. S. Geological Survey, pp. 144-151, excepting last seven, which were performed by J. G. Smith, Bureau of Soils, on samples collected by E. E. Frea.

TABLE XVI.—Quantity of saline material carried annually by certain rivers of the Great Basin.

Constituent.	Owens. ¹	Owens. ²	Humboldt.	Truckee.	Walker.	Bear River, Utah.
	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>
SiO ₂	9,460	12,967	8,818	22,432	4,827	.....
Fe.....	47.3	66.3	.....	.....	.....	.....
Ca.....	3,547	9,348	13,246	17,053	4,890	127,391
Mg.....	1,017	3,618	3,343	5,379	818	59,938
Na-K.....	9,460	20,807	15,355	26,797	6,822	258,634
HCO ₃	26,253	63,628	36,781	51,767	11,544	343,833
SO ₄	7,095	16,284	12,911	19,895	6,087	102,647
NO ₃	284	512	.....	.....	.....	.....
Cl.....	4,020	9,951	2,032	11,774	2,833	407,473
Total solids.....	44,701	102,228	92,851	155,335	37,783	1,259,235
Discharged into.....	Owens Lake.	Owens Lake.	Humboldt Lake.	Pyramid Lake.	Walker Lake.	Great Salt Lake.
Total solids, parts per million.	189	339	361	153	180	687
Mean annual flow, second-feet.....	240	306	261	1,030	213	1,860

¹ Owens River at Round Valley.

² Owens River at Charlie's Butte.

TABLE XVII.—Yield of salines per square mile of watershed per year.

Constituent.	Truckee. ¹	Walker. ¹	Humboldt. ²	Owens.	Tuolumne.	Yuba.	Kern.	San Luis Rey.	San Ysa-bel Creek.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
SiO ₂	29,524	6,972	128	16,200	54,822	113,580	301,970	17,368	244,006
Fe.....	.....	.....	48	82	947	1,703	2,516	67	942
Ca.....	22,443	7,063	1,919	11,680	49,838	105,475	301,970	23,532	160,855
Mg.....	7,080	1,182	484	4,560	21,431	34,887	70,461	7,284	72,108
Na.....	35,267	9,852	1,834	26,000	54,822	70,750	340,400	22,244	23,296
K.....	.....	.....	391	.....	5,482	10,385	28,688	2,409	.....
CO ₃	67,998	16,552	5,319	.....	.....	.....	.....	.....	7,210
HCO ₃.....	.....	.....	.....	79,400	204,340	389,436	1,191,130	91,333	887,500
SO ₄	26,183	8,591	1,871	20,200	59,807	105,475	352,307	29,696	166,407
NO ₃.....	.....	.....	.....	640	.....	.....	.....	.....	4,659
Cl.....	15,497	4,092	294	12,440	32,893	44,623	152,660	21,852	210,781
Totalsolids.....	203,992	54,304	11,288	127,600	368,800	681,516	2,130,600	179,850	1,442,166
Suspended matter.....	.....	.....	.....	.....	338,906	1,549,640	2,734,560	79,563	.....
Area, square miles..	1,520	1,100	13,800	1,600	1,500	1,220	2,345	318	128
Rainfall.....	.....	.....	.....	.....	15 in. +	15 in. +	15 in. +	Less than 15 in.	Less than 15 in.
Mean annual flow, second-feet.	1,030	213	261	306	3,793	5,023	1,996	90.4	45.35
Second-feet per square mile.	0.677	0.193	0.019	0.191	2.52	3.56	0.83	0.284	0.355
Pounds per square mile per second-feet per annum.	301,908	280,751	593,748	633,520	146,746	191,717	2,565,954	633,274	4,062,411

¹ Bnl. No. 491, Data of Geochemistry, p. 147.

² Ibid., p. 148.

TABLE XVIII.—*Analyses of alkali crusts.*¹

Description of sample.	Total soluble salts.	Percentage of total soluble salts.									
		Ca.	Mg.	Na.	K.	SO ₄	Cl.	HCO ₃ .	CO ₃ .	NO ₃ .	PO ₄ .
		P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
Alkali crust, Geary tract, Huntington, Utah, No. 1005a.....	43.2	1.39	5.40	22.08	0.35	69.00	1.38	0.40	.....	.....	.....
Goshen Valley, Provo, Utah, No. 794a.....	21.62	2.96	.97	32.44	2.71	1.18	59.25	.44	0.05	.....	.....
Provo, Utah, No. 793.....	11.03	.34	.30	33.26	1.25	3.55	21.70	15.16	21.44	.....	.....
Sanchez, Provo, Utah, No. 7.....	6.09	.52	.72	33.52	2.52	12.22	9.23	16.68	24.59	.....	.....
Sanchez, Provo, Utah, No. 6.....	2.15	1.48	2.70	24.98	3.16	45.91	6.51	10.98	4.23	.....	.....
South end Sevier Valley, Utah, from nook along river, No. 4725.....	36.99	1.05	Trace.	36.82	1.10	15.85	44.72	.65	.81	.....	.....
Black alkali crust, Sevier Valley, Utah, No. 4724.....	5.04	1.55	.32	31.28	2.86	17.68	33.46	12.49	.36	.....	.....
White alkali crust, Sevier Valley, Utah, No. 4723.....	3.03	5.55	Trace.	24.58	3.24	35.02	8.13	18.17	5.28	.....	.....
White alkali crust, Sevier Valley, Utah, No. 4722.....	5.27	2.62	.42	27.88	1.44	54.20	2.66	8.96	1.82	.....	.....
South end Sevier Valley, Utah, No. 4721.....	2.01	3.98	.60	22.97	6.36	12.23	23.76	30.11	.....	.....	.....
Alkali crust from hot spring, Montic, Sevier, Utah, No. 4718.....	37.33	1.78	.48	30.04	1.88	50.91	14.33	.19	.39	.....	.....
White alkali crust, Richmond, Utah, No. 4718.....	21.51	2.19	6.28	22.94	.34	38.91	28.74	.56	.....	.....	.....
White alkali crust from Richmond, Utah, along roadside, No. 4717.....	24.87	1.74	6.26	22.71	.41	44.81	22.86	1.21	.03	.....	.....
East of Joseph, Sevier County, Utah, near springs south end Sevier Valley Narrows, Oreg., No. 350a.....	18.36	3.08	.18	31.34	1.40	32.23	31.25	.39	.....	.....	.....
Truckee-Carson Project, Fallon, Nev.....	85.24	.08	.10	41.61	.43	3.38	3.39	3.19	50.82	.....	.....
Salt crust from south of Upper Surprise Lake, No. 95.....	100.0	.93	.50	39.46	.30	37.61	16.95	3.07	1.18	.....	.....
Salt crust from Salton Sea, near Monumere, No. 106.....	31.03	.26	.26	39.60	2.80	10.35	34.04	.10	11.69	Trace.	Trace.
Salt crust from Salton Beach, near Travertine rock, No. 113.....	40.57	3.65	1.62	30.21	.04	34.58	30.27	.23	.....	Trace.	Trace.
Salt crust from Imperial Junction Beach, No. 130.....	53.99	2.96	.72	28.38	.24	61.75	5.10	.85	.....	Trace.	Trace.
Salt crust from Imperial Junction Beach, No. 130.....	14.26	8.70	.56	25.55	.91	25.60	37.26	.42	.....	Trace.	Trace.
Averages.....	28.17	2.29	1.38	30.23	1.68	30.39	21.64	6.22	6.13	.....	.....

¹ Records of the Bureau of Soils.

TABLE XIX.—Analyses of salt and water samples taken in Railroad Valley, Nev.

[Analyses by A. R. Merz.]

No.	Description.	Total salts per 100 c. c.	Potash in total salts.
		Grams.	Per cent.
17		0.04	
18	Water from ditch in Hot Creek Canyon, 0.5 mile below source, Wager Ranch	.06	
21	Water from spring in Rattlesnake Canyon	.04	
23	Water from stream in Tybo Canyon at junction of canyon, 0.75 mile above store	.03	
25	Water from draw about 3 miles east of Warm Springs, Hot Creek Valley	.0680	
26	Salt crust at edge of this draw	2.07	5.25
27	Water from south ditch at west end of Twin Springs Pass	.0368	
28	Salt from flat south of this ditch	13.16	4.25
29	Water from north ditch; same locality	.08	
30	Salt crust from north side of this ditch	6.22	6.52
31	Water from spring at house in Twin Springs Pass	.03	
34	Water from stream at east end of Twin Springs Pass		
39		.0676	
40	Salt crust from edge of this stream	1.74	
42	Water from Mormon Well	.0256	
43	Surface salt crust here	4.55	5.29
45	Salt crust from seepage below terrace at Sharps' Ranch	27.36	5.05
47	Water from main spring, Sharps' Ranch	.0352	
48	Salt crust from flat near this spring	33.98	3.10
49	Water from well at Sharps	.04	
50	Water from Willow Spring	.05	
51	Standing water from outflow of Willow Spring onto flat	.18	
52	Water from Bullwhacker Springs	.0372	
53	Outflow from Bullwhacker Springs onto flat	.3352	
54	Salt from playa below Willow Springs, 1 mile northwest	25.24	.89
55	On same playa, 0.5 mile north of No. 54	22.74	3.28
56	Edge of main flat below Bullwhacker Springs	53.80	1.22
57	Salt from main flat, 0.25 mile west of No. 56	7.58	1.64
58	Salt crust from outflow flat of Willow Springs	33	5.87
59	Salt crust from surface near Bacon Springs	27.56	4.10
61	Water from Cold Spring, 1 mile north of Horton's Ranch	.0376	
62	Salt crust from surface near this spring	24.48	4.68
63	Water from draw 2 miles out of Allred, on Duckwater Road	.03	
64	Salt crust from soil surface in Duckwater Hills, 0.5 mile east of Duckwater	27.56	1.05
65	Water from ditch at Irwin Ranch	.0428	
66	Salt crust from near ditch here	12.10	1.65
70	Water from main spring at Lockes	.04	
71	Salt crust from surface near this spring	59.92	4.35
73	Water from spring on spring deposit well, 6 miles south of Lockes	.07	
75	Salt crust from near this spring	1.59	
76	Same, 100 yards southeast	4.55	8.53
80	Salt crust from draw, log 38 miles out of Lockes on road to R. R. V. Co. camp, east ditch of this draw	68.22	6.85
81	Same draw. Salt from ridge between ditches	56.63	2.98
82	Same draw. Salt from west ditch	55.72	3.67
84	Salt from surface in dune lands, log 55, out of Lockes to camp	14.69	4.06
87	Salt near road, log 60	30.46	4.53
88	Salt near road, log 6.5	24.03	2.35
89	First pan crossed by road. Salt just west of west edge, near road	25.58	5.71
90	Same pan, just east of west edge, near road	49.48	7.91
91	Same pan, salt from center 200 feet south of road	70.97	6.97
92	Same pan, center, 200 feet north of road	74.72	8.46
93	Same pan, just west of east edge, near road	56.37	7.54
94	Same pan, just east of east edge, near road	16.68	3.98
95	Salt from small draw at log 7.1, west edge	53	7.39
96	Same draw, east edge	71.64	9.20
97		69.12	7.72
98		55.16	9.22
99	Small draw at log 7.2, west side	64.95	8.52
100	Same draw as No. 99, main drainage line	66.62	5.76
101	From large pan on drainage line, the west side of which is at log 7.3, west edge just north of road	34.48	2.22
102	Same pan, one-third across from west side north of road	55.18	8.96
103	Same pan, just north of road at culvert	43.24	3.90
104	Same pan, extreme east edge, log 7.4	53.96	3.78
105	West edge of a drainage line just at head of salt flat (to south), log 7.7, north of road	72.64	6.38
106	Same, 100 feet east of No. 105	46.38	6.73
107	Same, 80 feet east of No. 106	76.38	5.00
108	Same, at culvert, 80 feet east of No. 107	60.02	3.41
109	Same, 110 feet east of No. 108	58.72	2.38
110	Same, extreme eastern edge, 125 feet east of No. 109	28.54	3.90

TABLE XIX.—Analyses of salt and water samples taken in Railroad Valley, Nev.—Con.

No.	Description.	Total salts per 100 c. c.	Potash in total salts.
		Grams.	Per cent.
111	First salty drainage line west of R. R. V. Co. camp, about 60 feet from west edge and 20 feet north of road.....	59.62	6.11
112	Same, main drainage line, 125 feet east of No. 111 and 125 feet north of road.....	59.16	5.45
113	Same, extreme eastern edge, 100 feet east of No. 112 (75 feet north of road).....	56.48	6.20
114	Small salt spot 420 feet east of No. 113 and 30 feet south of road.....	72.22	4.23
115	Surface salt at northeast end of salt flat, north of spring deposit hills, 6 miles south of Locke's Ranch.....	41.24	1.53
116	Same, about 0.25 mile southwest of No. 115.....	10.56	6.02
120	Salt from seepage on north side of southern of these hills.....	5.36	6.16
122	Salt from below spring on this latter hill.....	79.56	12.10
124	Main flat near camp. Salt from 97 feet west of southwest corner of Locke's claim.....	68.74	1.90
125	Same, 375 feet west of southwest corner Locke's claim.....	45.42	2.94
126	Same, 725 feet west of southwest corner Locke's claim.....	56.90	5.04
127	Same, 775 feet west of southwest corner Locke's claim.....	76.40	3.68
128	Same, 850 feet west of southwest corner Locke's claim.....	62.08	6.65
129	Same, 1,075 feet south of southwest corner Locke's claim.....	55.22	2.73
130	Water from old hole 40 feet east of point 1,250 feet south of southwest corner Locke's claim.....	20.87	8.54
131	Salt 1,350 feet south of southwest corner Locke's claim.....	83.40	4.53
132	Salt 1,250 feet south of southwest corner Locke's claim.....	40.42	2.06
133	Water from old hole 150 feet east of point 1,150 feet south of southwest corner Locke's claim. From upper (surface) stratum of brine.....	12.63	6.14
134	Water from corner stratum, same hole.....	13.04	6.23
135	Salt crust from 5 feet north this hole.....	68.64	3.39
137	Salt from 2,225 feet south of southwest corner Locke's claim.....	14.18	1.81
138	Water from old hole 50 feet east-southeast of southwest corner Fox claim.....	.97	1.16
139	Salt, 900 feet northwest of southwest corner Fox claim.....	47.18	1.30
140	Salt, 1,375 feet northwest of southwest corner Fox claim.....	15.74	5.94
143	Water from anger hole at location of No. 140.....	82.46	2.66
144	Salt 315 feet northeast of No. 140.....	41.34	2.83
145	.....	72.06	2.26
146	Same as No. 140.....	58.22	9.26
148	Salt from east side of first drainage line east of R. R. V. Co. camp.....	44.22	6.58
149	Salt 100 feet north of No. 148.....	29.80	4.83
152	Salt 150 feet north of southeast corner Locke's claim.....	11.62	11.92
153	Water from old hole 675 feet north of southeast corner Locke's claim, upper stratum of the brine.....	10.09	11.78
154	Water from lower stratum, this hole.....	69	10.17
155	Salt from 580 feet southwest of point 675 feet north of southeast corner Locke's claim.....	7.86	11.46
156	Water from hole 100 feet northwest of No. 155.....	.076	
157	Water from McDonald spring.....	12.58	5.03
158	Water from new hole 450 feet southeast of point 1,620 feet southwest from McDonald spring.....	67.92	3.79
159	Salt crust 5 feet north of this hole.....	48.92	1.48
162	Salt 879 feet toward McDonald spring from No. 158.....	13.99	5.49
163	Water from lower brine stratum from old hole 200 feet northwest and 80 feet southwest from No. 158.....	13.97	5.82
164	Water from old hole 390 feet northeast of No. 163.....	64.62	3.26
165	Salt from 5 feet east of No. 163.....	76.58	3.42
166	Salt from 5 feet south of No. 164.....	.07	
167	Water from well at R. R. V. Co. camp.....	41.10	1.53
168	Salt from northwest corner of main flat, 0.25 mile southeast of road at log 4 miles out of R. R. V. Co. camp toward Locke's ranch.....	.04	
171	Water from Black Rock Springs.....	.07	
175	Water from Hot Creek at bridge at Barndt's house.....	.08	
176	Main hot spring at Barndt's.....	.05	
177	Water from Hot Creek above Hot Springs at Barndt's. From high ditch.....	.08	
178	Water from Warm Springs.....	.05	
186	Water from a warm spring about 0.5 mile northeast of Locke's ranch.....	.05	
187	Water from well at Horton's house, Blue Eagle.....	.05	
188	Water from cold spring at Blue Eagle, 100 yards northwest Horton's house.....	.05	
189	Water from warm spring here, 50 yards west of Horton's house.....	.04	

TABLE XX.—*Analyses of saline crusts found in Railroad Valley.*

[Parts per 100,000. Analyses by J. A. Cullen.]

No.	Ca.	Mg.	K.	Na.	SO ₄ .	Cl.	CO ₃ .	HCO ₃ .	Total solids.
76.....	12	6	322	1,509	987	640	600	732	4,808
92.....	10	4	5,248	24,549	7,800	30,800	2,640	5,856	76,379
96.....	10	4	5,473	23,799	4,443	34,020	1,800	3,782	73,331
102.....	10	3	4,105	21,817	3,785	33,040	600	1,342	64,702
154.....	40	12	987	39,475	555	6,650	None.	31	12,605
Brine.....				25,475					
155.....	12	6	5,826	25,475	7,734	38,360	180	427	78,020

76. Salt crust near spring 6 miles south of Locke's claim.

92. Center salt pan at road crossing.

96. East edge draw.

102. Salt pan.

154. Water from lower stratum; water hole southeast corner Locke's claim.

155. Salt from 580 feet southwest of point 675 feet north of southeast corner Locke's claim.

TABLE XXI.—*Analyses of Death Valley brines.*

[Parts per 100,000.]

No.	Ca.	Mg.	K.	Na.	Cl.	SO ₄ .	CO ₃ .	HCO ₃ .	Total solids.
1a.....	57.1	135.6	1,197.7	12,339.4	18,557.5	2,057.0	Tr.	38.0	34,606.4
2a.....	64.3	120.3	913.4	12,389.8	18,557.5	1,978.8	Tr.	38.0	34,138.6
3a.....	71.4	94.0	683.3	12,456.6	18,620.0	1,900.6	Tr.	45.8	34,122.0
4a.....	71.4	133.3	1,361.7	12,426.1	18,620.0	2,324.4	30	45.8	35,057.0
5a.....	92.9	113.7	1,170.0	12,522.3	18,620.0	2,336.8	15	30.5	35,318.0
6a.....	71.4	98.4	1,183.0	12,602.0	18,620.0	2,349.1	30	45.8	35,243.0
7.....	71.4	63.4	383.6	12,465.9	18,690.0	1,324.7	15	45.8	33,148.0
8.....	92.9	40.3	349.8	12,442.9	18,830.0	1,053.2	Tr.	30.5	32,817.0
9.....	85.7	35.2	372.4	12,558.7	18,690.0	1,468.7	Tr.	30.5	33,540.0
Average.....	79.6	97.6	907.0	12,451.3	18,620.2	1,947.8	22.2	39.9	34,470.0

Sample No. 1a taken from hole about 5.5 miles northeast from Eagle Borax Works. (Size of hole 16 feet deep, 2.5 feet long, and 2 feet wide.)

Sample No. 2a taken about 6 miles northeast from Eagle Borax Works. (Size of hole 2 feet wide, 2 feet long, 3 feet deep, out on smooth salt 1,000 feet from rough salt.)

Sample No. 3a taken 0.5 mile east from sample 2a. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 4a taken 0.5 mile east from sample No. 3a. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 5a taken 1 mile north from sample No. 4a. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 6a taken 0.5 mile west of sample 5a. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 7 taken 1 mile north of sample No. 3a on smooth salt in hole 10 feet deep, 3 feet wide, 4 feet long.

Sample No. 8 taken from pothole 0.5 mile north of sample No. 7. Depth of hole unknown, but very deep. Four feet in diameter. Only 1 sample marked No. 8. Sample No. 8 taken on rim of rough salt.

Sample No. 9 taken 1 mile north from pothole No. 8 on rough salt. Depth of hole unknown.

Samples taken by J. H. Jones. Analyses by J. A. Cullen.

TABLE XXII.—*Analyses of waters and brines.*

[Samples collected by E. E. Free. Analyses by A. R. Merz.]

No.	Description.	Total solids per 100 c. c.	K ₂ O in total solids.
			<i>Per cent.</i>
306	Slough at first crossing, road from Furnace Creek to Bennetts Wells.....	36.51	3.42
307	Water from hole 18 feet deep, 1 mile north of sink (saline pond northeast of Bennetts Wells).....	20.36	1.08
326	Surface water from near road from Furnace Creek to Bennetts Wells, 10 miles from Furnace Creek Road.....	10.42	1.50
327	Water from 10-foot dug hole on this road, 9.7 miles west of Furnace Creek.....	36.81	3.31
331	Water from 4-foot dug hole at U. S. Geological Survey, B. M. 72, on road from Furnace Creek Ranch to Bennetts Wells.....	33.80	.96
338	Water from hole in mud flat northwest of Furnace Creek 7,500 feet northwest from land monument at old borax works north of Furnace Creek, hole 2 feet deep.....	33.28	3.08
339	West side of valley, due west from Furnace Creek Ranch, water from dug hole 3 feet deep.....	2.77	1.75
341	Water from dug hole 0.25 mile east of No. 339, 2.5 feet deep.....	15.12	2.38
342	Water from dug hole 0.25 mile east of No. 341, depth 7 feet. On main flat.....	34.18	2.98
343	Water from surface pool at old bridge due west of Furnace Creek Ranch (Skidoo trail).....	32.05	2.25

TABLE XXIII.—*Analyses of muds and clays.*

[Samples collected by E. E. Free. Analyses by A. R. Merz.]

No.	Description.	Total soluble solids.	K ₂ O in total soluble solids.
		<i>Per cent.</i>	<i>Per cent.</i>
316	Death Valley flat, east side, 500 yards west of road, 5.4 miles south of Furnace Creek Ranch, surface salt.....	22.17	0.39
317	665 feet east of Bennetts Wells, salt from surface of slough bottom.....	10.65	1.79
319	Clay from 3 feet under surface, 1 mile east of Bennetts Wells.....	12.16	2.22
320	Clay from shallow hole 0.25 mile east of No. 319.....	21.49	1.12
323	Water squeezed from clay obtained from hole in slough 1,800 feet east of Bennetts Wells.....	18.24	3.03
335	Sandy clay, bottom of hole east side of valley on road from Furnace Creek to Bennetts Wells.....	25.54	2.09

TABLE XXIV.—*Analyses of alkaline Death Valley soils.*

[Parts per 100,000.]

No.	Ca.	Mg.	K.	Na.	SO ₄ .	Cl.	CO ₂ .	HCO ₃ .	Total solid.
20.....	343	44	193	38,460	823	59,360	None.	122	99,312
21.....	456	44	438	14,161	2,402	21,000	None.	240	38,678
22.....	3,200	380	3,316	14,364	13,390	19,740	600	732	55,239
23.....	257	35	290	37,893	987	58,240	None.	122	97,783
24.....	229	35	226	35,608	527	59,600	None.	122	99,415

Description:

20. Salt crust from Death Valley 3 to 6 inches thick, opposite Telescope Peak.
 21. Clay underlying salt crust. Opposite Telescope Peak.
 22. Heaved ground near periphery. Opposite Telescope Peak.
 23. Pothole 5 feet in diameter, 10 feet deep. Salt from margin of pothole.
 24. Hairlike salt from edge of hole.
 Analyses by J. A. Cullen. Samples by G. J. Young.

TABLE XXV.—Analyses of various samples from Searles deep well.

No.	Total.		Water soluble.		Insoluble.	
	K.	Na.	K.	Na.	K.	Na.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
209.....	3.48	4.72	0.23	2.54	3.25	2.18
211.....	4.26	5.96	.27	4.81	3.99	1.15
212.....	1.14	29.94	.91	30.34	.23	.0
213.....	2.64	14.14	.44	11.23	2.20	2.91
214.....	.46	16.91	.09	8.43	.37	8.48
215.....	.78	24.05	.26	11.81	.52	12.24
216.....	3.07	10.21	.42	7.66	2.65	2.55
217.....	1.58	19.77	.09	12.27	1.49	7.50
218.....	3.79	7.31	.59	5.28	3.20	2.03
220.....	2.73	9.95	.42	7.94	2.31	2.01
221.....	2.30	9.13	.43	7.48	1.87	1.65
222.....	1.55	6.13	.06	.64	1.49	5.29
223.....	2.98	5.70	.25	4.64	2.73	1.10
224.....	1.52	6.51	.28	5.68	1.24	.83
225.....	2.28	5.31	.20	2.34	2.08	2.97
226.....	2.79	7.75	.58	5.70	2.21	2.05
227.....	.98	32.03	.70	31.23	.28	.80
228.....	1.44	10.28	.48	6.40	.96	3.88
229.....	4.19	6.36	.33	4.23	3.86	2.13

209. Marked "Deep well, Mar. 9, 1896. Soft clay overlying at hard streak 62.5 feet."
211. Marked "Deep well, Mar. 9, 1896. Clay from bottom of well to date. 227 feet 10 inches. K-S."
212. Marked "Crystal deposited by standing over night from water taken from well at 600 feet. Source of water we presume at 400 feet."
213. Marked "From deep well Sept. 2, 1895, at 409 feet. Depth of deposit 408 to 427 feet."
214. Marked "Crystal at 427 to 442 feet. Drilling hard as rock."
215. Marked "* * * with bed of No. 3. 442 to 469 feet."
216. Marked "Deep well No. 4. 469 to 500 feet."
217. Marked "Green mud with No. 5. Strong ammonia smell from 506 feet. Dec. 31, 1895. Depth of deposit 500 to 515 feet."
218. Marked "Depth of deposit No. 6. 515 to 520 feet."
220. Marked "From 535 feet on Jan. 8, 1896. Depth of Deposit 530 to — feet. No. 8."
221. Marked "Rimmings from deep well, Borax Lake, at 540 feet. Showing formation in clear parallel lines."
222. Marked "Washings from mud of deep well at 540 feet."
223. Marked "Jan. 13, 1895, from 575 feet."
224. Marked "Jan. 15, 1896, from 580 feet."
225. Marked "Rimmings between 586 and 5*6 feet ***."
226. Marked "Deep well at 600 feet, Mar. 5, 1896."
227. Marked "Crystals from water at 600 feet."
228. Marked "Deep well at 620 feet, Mar. 9, 1896."
229. Marked "Black and gray mud taken from deep well at 627 feet. Black turns gray on exposure."

TABLE XXVI.—Sodium-potassium ratios for samples from Searles deep well.

No.	Soluble Na/K.	Insoluble Na/K.	Total Na/K.	No.	Soluble Na/K.	Insoluble Na/K.	Total Na/K.
209.....	10.9	0.67	1.32	221	17.42	0.88	3.97
211.....	18.1	.28	1.40	222	11.35	3.54	4.47
212.....	33.2	.0	26.25	223	18.60	.40	1.91
213.....	25.75	1.32	5.36	224	20.6	.67	4.28
214.....	98.0	23.0	36.70	225	11.85	1.43	2.33
215.....	46.0	23.5	30.75	226	9.73	.98	2.78
216.....	18.5	.96	3.92	227	44.7	2.86	32.75
217.....	147.0	5.05	12.5	228	13.5	4.05	7.12
218.....	8.95	.635	1.93	229	12.8	.55	1.52
220.....	19.17	.9	3.65				

TABLE XXVII.—Composition of alkali samples from deep bore in Searles marsh.

No.	Ca.	Mg.	K.	Na.	Cl.	SO ₄ .	CO ₃ .	HCO ₃ .	Total soluble salts.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
209.....	0.094	0.020	0.23	2.54	3.47	2.40	Tr.	0.32	9.07
211.....	Tr.	.010	.27	4.81	5.27	2.79	0.12	.36	13.63
212.....	Tr.	.008	.91	30.34	10.73	45.14	1.63	2.64	91.40
213.....	Tr.	.084	.44	11.23	6.36	3.78	3.74	6.59	32.21
214.....	.038	.221	.09	8.43	2.46	.37	5.34	8.15	25.09
215.....	Tr.	.192	.26	11.81	3.96	1.08	6.10	12.10	35.49
216.....	.038	.004	.42	7.66	7.15	5.31	1.16	2.32	23.95
217.....	.043	.006	.09	12.27	9.37	3.00	3.85	5.05	33.67
218.....	Tr.	.009	.59	5.28	5.27	3.39	.37	.85	15.76
220.....	Tr.	.045	.42	7.94	7.57	3.94	1.09	1.76	22.76
221.....	Tr.	.020	.43	7.48	3.57	1.84	3.61	4.76	21.71
222.....	Tr.	.004	.06	.64	.45	.21	.15	.34	1.97
223.....	.108	.015	.25	4.64	4.60	3.56	.15	.31	13.64
224.....	Tr.	.006	.28	5.68	5.82	3.48	.27	.52	16.06
225.....	.043	.006	.20	2.34	2.65	1.43	.09	.12	6.88
226.....	.050	.010	.58	5.70	6.32	3.55	.21	.40	16.82
227.....	Tr.	.008	.70	31.23	11.94	45.66	1.63	1.96	93.12
228.....	Tr.	.008	.48	6.40	7.78	2.74	.15	.56	18.12
229.....	.065	.012	.33	4.23	4.55	2.98	.06	.25	12.48

TABLE XXVIII.—Composition of soluble salts in samples from deep bore in Searles marsh.

No.	Ca.	Mg.	K.	Na.	Cl.	SO ₄ .	CO ₃ .	HCO ₃ .
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
209.....	1.04	0.21	2.52	22.93	26.38	20.64	Tr.	3.48
211.....	Tr.	.07	1.95	34.00	39.76	22.49	0.89	2.61
212.....	Tr.	.01	1.00	28.17	11.70	54.08	1.77	2.88
213.....	Tr.	.26	1.35	32.64	19.74	12.76	11.57	20.41
214.....	.15	.88	.35	33.53	9.80	1.47	21.24	32.45
215.....	Tr.	.54	.72	33.20	11.17	3.14	17.19	34.13
216.....	.16	.01	1.74	34.03	29.91	24.34	4.83	9.68
217.....	.13	.02	.25	35.59	27.84	9.78	11.43	15.00
218.....	Tr.	.06	3.72	31.38	33.42	23.59	2.31	5.40
220.....	Tr.	1.97	1.79	33.26	33.24	25.91	4.67	7.72
221.....	Tr.	1.12	1.97	33.60	16.43	13.30	16.61	21.93
222.....	Tr.	.15	2.85	31.63	22.93	11.78	7.74	22.91
223.....	.72	.11	1.83	32.55	33.76	27.55	1.11	2.27
224.....	Tr.	.04	1.71	33.82	37.19	23.77	1.69	3.25
225.....	.62	.09	2.87	32.17	38.48	22.67	1.31	1.77
226.....	.29	.06	3.44	31.85	37.53	23.06	1.26	2.37
227.....	Tr.	.01	.74	28.56	12.79	53.70	1.74	2.10
228.....	Tr.	.04	2.62	33.83	42.99	16.61	.83	3.06
229.....	.52	.09	2.66	32.00	36.98	26.08	.48	1.98

TABLE XXIX.—Analyses of water and mud from Searles Lake well, Cal.

[Samples collected by E. E. Free. Analyses made by A. R. Merz].

Description of samples.	Total soluble solids.	K ₂ O in total soluble solids.
	<i>Per cent.</i>	<i>Per cent.</i>
356. A VII, water 20 feet down.....	42.8	6.08
357. E 5, mud from 40 feet.....	36.88	1.41
358. E 5, water from bottom, 48 feet.....	29.98	3.04
359. E 4, water from bottom, 70 feet.....	25.43	2.06
360. E 4, mud from bottom.....	35.26	0.50
361. E 3, water from 42½ feet, artesian.....	29.60	2.88
362. E 3, mud from 75-80 feet.....	19.86	2.18
363. E 2, water from 60 feet.....	35.9	2.52
364. E 2, mud from 98 feet.....	54.80	2.29
365. E 1, water from 100 feet.....	25.4	1.35
366. E 1, mud 41 feet.....	49.52	0.46
367. E 2, mud and crystals from 70 feet.....	60.99	0.516

E 1. Southwest corner section 14, township 26 S., range 43 E.

E 2. Southwest corner section 11, township 26 S., range 43 E.

E 3. Southwest corner section 10, township 26 S., range 43 E.

E 4. Slightly north and east of middle of west line section 10, township 26 S., range 43 E.

E 5. Slightly north and west of middle of east line, section 17, township 25 S., range 43 E.

TABLE XXX.—*Petrographic examination of samples from Searles deep well.*

[Analyses by J. C. Jones.]

No.	Description.
209	Similar to 221 and 213.
211	Fine-grained tourmaline, biotite, hornblende, plagioclase, and quartz grains recognized. Major part of material clay cemented by gaylussite.
212	Larger grains pirssonite, limonite, a few quartz grains.
213	A fine mud cemented by carbonates with a few fragments of quartz, hornblende, tourmaline, and iron oxide.
214	Crystals of pirssonite with inclusions of clay and iron oxide.
215	Mostly crystals of pirssonite, some halite, grains of quartz, clay, and iron oxides.
216	Pirssonite in broken crystals, limonite, kaolin, biotite, tourmaline, quartz. Fine-grained material average diameter, 0.5 mm.
217	Crystals of pirssonite, nodules of limonite, a few grains of quartz, hornblende, plagioclase.
218	Mostly clay and iron oxide cemented by carbonates; some grains of quartz, hornblende, biotite, and a few clouded and decomposed orthoclase crystals noted.
220	Mostly clay cemented by pirssonite; mineral fragments of quartz, hornblende, tourmaline, biotite, apatite, and many fresh and clouded fragments of microcline, approximately about 25 per cent of the mineral fragments left after washing out clay and dissolving carbonates. This is the only sample in which feldspar crystals approaching freshness were noted.
221	A fine mud firmly cemented by carbonates with a few fragments of quartz, hornblende, and hydrated biotite.
222	Oolitic sand; rounded grains composed of minute grains of quartz cemented in part by carbonates and iron oxide but retaining form after being acted on by acid. Not a true oolite as no concentric structure could be noted.
223	Fine-grained clay grains of quartz, hornblende, biotite, cemented by carbonates.
224	Similar to No. 223.
225	Fine-grained clay, cemented by carbonates, grains of tourmaline, quartz, hornblende, apatite, and biotite.
226	Similar to No. 223.
227	Grains about 1 millimeter in diameter, gaylussite, limonite, quartz.
229	Similar to No. 225.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 62



Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
January 14, 1914.

TESTS OF THE WASTE, TENSILE STRENGTH, AND BLEACHING QUALITIES OF THE DIFFERENT GRADES OF COTTON AS STANDARDIZED BY THE UNITED STATES GOVERNMENT.

By N. A. COBB, *Agricultural Technologist in Charge of Agricultural Technology and Cotton Standardization.*

ORIGIN AND LOCATION OF THE EXPERIMENTS.

The Department of Agriculture is not interested directly in textile work. Its interest is indirect and arises largely from the fact that Congress has selected it as the governmental agent for the establishment of the official cotton grades and for the study of cotton standardization. Many of the experiments of the department are therefore directed toward ascertaining certain facts that will assist in making the official cotton grades more useful and more reliable.

The official cotton grades at present take cognizance of only two of the important qualities which determine the value of cotton, namely, (1) the color and (2) the amount of trash and waste matter. Any complete system of standardization of cotton will, however, have to take into consideration, among other things, (3) the length of the fiber, (4) the strength of the fiber, (5) the clinging qualities of the fiber, and (6) the bleaching qualities of the fiber. Most of these qualities are of such a nature that they can be satisfactorily determined only by means of spinning tests, and it is for this reason that the department for several years has been making spinning tests with cotton in the mills and textile schools of the country. Experiments have been undertaken, among other places, at the following institutions and mills: Clemson Agricultural College, Textile Department, Clemson, S. C., Lowell Textile School, Lowell, Mass., Mississippi Agricultural and Mechanical College, Agricultural College, Miss., North Carolina Agricultural and Mechanical Textile School, Raleigh, N. C., and at various mills in South Carolina, North Carolina, Missouri, Virginia, Massachusetts, and Maine—about a dozen different mills in all. The experiments consisted in spinning cotton of known history into yarn under definite conditions as nearly as possible approaching commercial conditions. The qualities of the resulting yarn have been tested, and by comparison the desired results have been secured.

In this way it has been shown how cotton is affected—that is, improved or injured—when grown in certain ways or handled in certain ways.

The last appropriation bill of the Department of Agriculture was so amended in the Senate as to direct the Secretary of Agriculture to make tests as to the waste, tensile strength, and bleaching qualities of the various grades of cotton as established by the Government.

These experiments are being conducted in part at the Riverside and Dan River Cotton Mills, at Danville, Va., and are being so carried out as to reserve at each stage of the manufacture a liberal supply of the material. It is intended that this reserve shall be used in making 50 sets of exhibits to accompany the full report. Each exhibit will consist of 25 to 50 boxes or cases containing samples of waste, sliver, roving, yarn, etc., of such size that their commercial qualities can be estimated by those versed in the art. It is intended to distribute these exhibits in such a way as to make them accessible to growers, buyers, manufacturers, and educational institutions.

COTTON USED IN THE EXPERIMENTS.

In making these waste, tensile strength, and bleaching tests of the official grades of cotton, only the grades Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary have been used. This method makes it possible to test a larger number of bales of the respective grades and so gives a more accurate average. The qualities of the intermediate grades may then be interpolated. Since there is some difference in the spinning characteristics of eastern and western Upland cotton, the test has been divided into two parts. From 50 to 60 bales of the two respective growths, or an aggregate of 100 to 120 bales have been selected; that is, 10 to 12 bales of each grade of both Atlantic States Upland and Western Upland cotton. In order that the tests may be comparative, each lot has the same length of staple—1 inch. There is probably more staple produced which is fifteen-sixteenths of an inch to 1 inch than any other one length in both the eastern and western Upland cotton. The term "Western Upland" as here used includes practically all cotton grown west of Alabama, except long-staple river-bottom cotton.

The cotton was secured in June, 1913, from the following places:

Greenville, S. C., 6 bales, Atlantic States Upland cotton.
Seneca, S. C., 5 bales, Atlantic States Upland cotton.
Atlanta, Ga., 34 bales, Atlantic States Upland cotton.
Atlanta and Montgomery, 18 bales, Atlantic States Upland cotton.
New Orleans, La., 9 bales, Western Upland cotton.
Mobile, Ala., 32 bales, Western Upland cotton.
Memphis, Tenn., 5 bales, Western Upland cotton.
Lesser-Goldman, St. Louis, Mo., 12 bales, Western Upland cotton.
New Orleans, La., 2 bales, Western Upland cotton.

The cotton thus secured has been supplemented by a few bales from other sources. This cotton was shipped early in July to Danville, Va., where all of it was stored on the same warehouse floor and allowed to stand until October 1, so that the bales, in spite of their varied origin, might come to the same condition as to moisture, etc.

Thirty-five pounds from each bale have been sent to the textile department of Clemson Agricultural College, Clemson, S. C., and 35 pounds to the North Carolina Agricultural and Mechanical Textile School at Raleigh, N. C. Thirty pounds of each bale are to be reserved for use in the preparation of record sets.

The 10 to 12 bales of each grade remaining at the Danville mills have been thoroughly mixed and allowed to stand for a day or two just before entering the beaters. A composite sample was taken from each lot of 10 to 12 bales so mixed, and this was sent to Washington for accurate tests of various kinds.

MILL CONDITIONS OF THE EXPERIMENTS.

The same number of yarn (20-22) has been made at the mill from each grade, using the regular mill machines and methods, with the speeds, settings, relative humidity, and other factors the same for each grade of cotton. The organization and other figures were determined after consultation with a number of representative American mills, the officers of which generously undertook to examine and comment on the figures first determined upon by the experts of the Department of Agriculture, Messrs. D. E. Earle and W. S. Dean. In this way mill conditions representative of American practice were secured, as shown in Table I.

TABLE I.—*Organizations, speed, and settings used with regular mill machines for five official cotton grades.*

ORGANIZATIONS.¹

No. of yarn.	Card.		Drawing, grains per yard.	Slubber, hank.	Inter- mediate, hank.	Roving, hank.	Spinning, doubling.
	Lap, ounces per yard.	Sliver, grains per yard.					
12.	16	65	60	0.55	1.6	.....	1
16.	14	60	60	.55	1.4	2.6	1
22.	13	52	52	.47	1.16	3.33	1
28.	12	50	50	.75	1.7	5.4	2
36.	10	45	45	.80	2.2	6.5	2

¹ These figures, of course, do not refer to mills devoted to specialties.

TABLE I.—Organizations, speed, and settings used with regular mill machines for five official cotton grades—Continued.

SPEEDS (R. P. M.).

Machine.	No. 12's from Good Ordinary.	No. 16's from Low Middling.	No. 22's from Mid- dling.	No. 28's from Good Middling.	No. 36's from Mid- dling Fair.
Opener beater (3-blade).....	1,170	1,170	1,170	1,170	1,170
Breaker beater (2-blade).....	1,460	1,460	1,460	1,460	1,460
Fan.....	1,260	1,260	1,260	1,260	1,260
Intermediate beater (2-blade).....	1,460	1,460	1,460	1,460	1,460
Fan.....	900	900	900	900	900
Finisher beater (2-blade).....	1,460	1,460	1,460	1,460	1,460
Fan.....	900	900	900	900	900
Card cylinder.....	165	165	165	165	165
Doffer.....	13	13	12	12	12
Drawing, calendar roll.....	315	315	315	315	315
Slubber F. R., 11×5½.....	195	192	192	175	130
Intermediate F. R., 9×4½.....	182	182	160	157	150
Fine-frame F. R., 7×3½.....	180	180	130	130	120
Spinning F. R.....	150	140	120	114	108
Spindle.....	7,500	8,000	8,200	9,000	9,000

SETTINGS.

Machine.	No. 12's from Good Ordinary.	No. 16's from Low Middling.	No. 22's from Middling.	No. 28's from Good Middling.	No. 36's from Mid- dling Fair.
	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>
Opener-feed roll to beater.....	$\frac{3}{8}$				
Grids from beater (top).....	1	1	1	1	1
Grids from beater (bottom).....	$1\frac{1}{2}$				
Breaker-feed roll to beater.....	$\frac{1}{2}$				
Grids from beater (top).....	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Grids from beater (bottom).....	1	1	1	1	1
Intermediate-feed roll to beater.....	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Grids from beater (top).....	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Grids from beater (bottom).....	1	1	1	1	1
Finisher-feed roll to beater.....	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Grids from beater (top).....	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Grids from beater (bottom).....	1	1	1	1	1
Card:	<i>Gauge.</i>	<i>Gauge.</i>	<i>Gauge.</i>	<i>Gauge.</i>	<i>Gauge.</i>
Feed plate to licker in.....	10	10	10	10	10
Mote knives (top).....	12	10	10	10	10
Mote knives (bottom).....	10	12	12	12	12
Licker in to cylinder.....	10	10	10	10	10
Back plate to cylinder.....	22	22	22	22	22
Flats to cylinder (back).....	11	11	11	11	11
Flats to cylinder (center).....	10	10	10	10	10
Flats to cylinder (front).....	9	9	9	9	9
Front plate to cylinder.....	29	22	22	22	22
Doffer to cylinder.....	7	7	7	7	7
Doffer comb to doffer.....	22	22	22	22	22
Licker in screen (front).....	125	125	125	125	125
Licker in screen (back).....	22	22	22	22	22
Cylinder screen (back).....	22	22	22	22	22
Cylinder screen (center).....	70	70	70	70	70
Cylinder screen (front).....	125	125	125	125	125
Drawing (2 processes).....	$1\frac{3}{8}, 1\frac{1}{2}, 1\frac{5}{8}$	$1\frac{3}{8}, 1\frac{1}{2}, 1\frac{5}{8}$	$1\frac{3}{8}, 1\frac{1}{2}, 1\frac{5}{8}$	$1\frac{3}{8}, 1\frac{1}{2}, 1\frac{5}{8}$	$1\frac{3}{8}, 1\frac{1}{2}, 1\frac{5}{8}$
Slubber rolls.....	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$
Intermediate rolls.....	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$
Fine fly frame rolls.....	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$
Spinning rolls.....	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$	$1\frac{1}{8}, 1\frac{1}{4}, 1\frac{3}{8}$

In spite of the fact that some of the grades would rarely be spun into yarn of these sizes, it was thought best for various reasons to spin all the grades into one size of yarn at the Danville mill. The same cotton will be used in smaller quantities at the two textile schools and spun as nearly as possible under the same conditions. At one of the schools the mill tests will be duplicated; at the other a varia-

tion will be introduced, in that each grade will be used to spin the size of yarn for which it is best adapted, so that when the entire series of experiments is completed the results will present as many sided a view of the question as possible.

Approximately two bales of each grade have been bleached in the raw and the same number of yarn made from each bleach at Danville. With the exception of one bale of western Good Ordinary no difficulty was encountered in bleaching.

About 25 pounds of waste, or as much thereof as is produced on the different machines for the respective grades, have been marked and sent to Washington, where waste types will be prepared for the determination of value. For careful examination, as well as for exhibition purposes, the following types of waste have been collected from each of the 10 tests:

About 25 pounds of opener and breaker lapper notes.

About 25 pounds of intermediate lapper notes.

About 25 pounds of finisher.

About 25 pounds of card strippings.

About 25 pounds of card toppings.

About 25 pounds of card flyings and notes.

A record of the white waste made in spinning the respective grades has also been made, as well as the scavenger and clearer waste. Hygrometers have been placed in the various mill rooms and readings made hourly. A relative humidity of about 55° for the picker and card rooms and 65° for the spinning room has been maintained so far as practicable.

NATURE OF THE COTTON SECURED FOR THE EXPERIMENTS.

No serious difficulty was encountered in securing in the month of June, 1913, sufficient cotton for both of these tests. It was, of course, necessary, considering the nature of the experiment, that each bale of cotton be of very uniform character and exactly of the specified grade. It was not deemed wise to accept a lot of 10 or 12 bales which would merely average the specified grade. No bale was accepted unless, when the bands were removed and the bale opened up and sampled in 12 different places, it proved to be of very uniform character. Purchasing cotton in this way is a very different matter from purchasing an average lot for ordinary mill purposes, where considerable latitude can be allowed so long as the average of the purchase is about on grade. Nevertheless, as before stated, no very great difficulty was encountered. In Low Middling Atlantic States Upland cotton it was necessary to accept a few bales of a slightly bluish cast, differing to a small extent in color from the box types of the official grades. Samples drawn from the accepted bales have been inspected by dozens of well-known experts from all parts of the

cotton-growing and cotton-manufacturing regions of the United States, and these experts without exception declared the bales to be excellently selected.

While this cotton is now well through the mill, so that the success of the experiment is assured, it is not yet possible to draw more than tentative and approximate conclusions on a number of points. It seems safe, however, to make the following statements.

PERCENTAGE OF WASTE.

The two classes of cotton, Western Upland and Atlantic States Upland, have yielded a visible waste of slightly different weight and character, the average difference in the percentage of waste being between 1 and 2 per cent, taking all the grades into consideration. This difference obtained in the mill has been paralleled by carefully made hand separations. In the hand separations, the average difference in waste was about $1\frac{3}{4}$ per cent. On the whole, as would be expected, the differences are considerably greater in the lower grades than in the higher grades. The highest difference so far noted was the following, but so large a difference appears altogether exceptional.

Visible waste (hand separated).—Atlantic States Upland Good Ordinary, 12.49 per cent; Western Good Ordinary, 7.80 per cent.

Mill waste (visible).—The corresponding minimum difference was as follows: Atlantic States Upland Good Ordinary, 12.57 per cent; Western Good Ordinary, 10.08 per cent.

VALUATION OF THE WASTE.

The value of the visible waste from the various grades has yet to be determined, but from its character there can be little doubt that the valuation figures for the waste of the two classes of cotton will be approximately equal, weight for weight.

TENSILE STRENGTH OF THE YARN.

Preliminary and approximate figures have been obtained concerning the tensile strength of the yarns. These tests show the yarn from the two classes of cotton to be about equal in strength.

As regards the relative amount of visible waste in the different grades, the figures are found to be more consistent than might have been expected. The mill waste in the experiments to date varies from about 4 per cent in Middling Fair to about 11 per cent in Good Ordinary, and the various official grades tested fall into line with something approaching mathematical uniformity, as will be seen by examination of the following graph (fig. 1).

LENGTH OF STAPLE USED.

It must be carefully borne in mind that the cotton used in these investigations was all of the same length of staple. It will be seen from an examination of the purchasing sources that most of the Atlantic States Upland cotton has probably come from the Piedmont and similar sections. An examination of the Census Bureau statistics for the last five years indicates that about half of the Atlantic States Upland cotton of the character used in these experiments originates in these sections. The other half of the cotton used in the tests came from the Gulf States and Arkansas.

CONDITIONS UNDER WHICH THE EXPERIMENTS WERE MADE.

Although the foregoing figures and statements are the result of experiments on only one season's cotton, they are presented with confidence in their approximate accuracy so far as they go. The investigations have been carried out under favorable auspices and

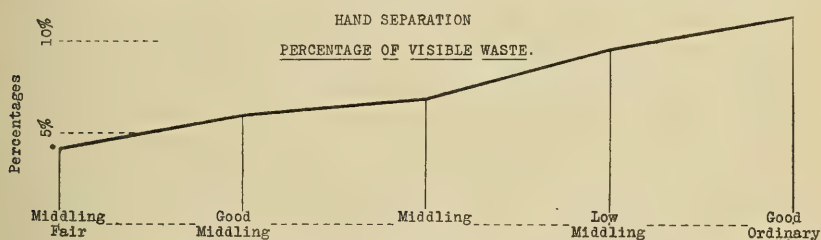


FIG. 1.—Graph showing the percentage of visible waste in five of the official cotton grades. The waste in this case was obtained by hand separation.

have been attended with good fortune. The only exception to this has been that unsuitable weather occurred during a part of the spinning. No detail received greater attention than that of suitable and uniform humidity. Among other precautions taken was the halting of the experiments for three months in order that the work might be done during the most suitable spinning months for the region (Danville, Va.), namely, those of October and November. Hence, the mill experiments began on October 1, 1913.

Unfortunately, however, the weather during the first weeks of October was about the most varied that had ever been experienced at Danville. Everything was done to offset this disadvantage by as careful control of the humidifiers as possible. Furthermore, the precaution of reserving 200 pounds of each grade somewhat short of the spinning stage had been observed, and it was possible later to put this weight of each grade through the spinning processes on the same day, thus securing a relatively small amount of yarn more strictly comparable than would otherwise have been possible. The final figures will be ready for publication in the course of a few months.

SUMMARY.

In accordance with the last appropriation bill of the Department of Agriculture, tests as to the waste, tensile strength, and bleaching qualities of the different grades of cotton as established by the Government have been carried on in order to ascertain certain facts which would make the official cotton grades more useful and reliable.

About 10 or 12 bales of each of the five grades Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary, of both Atlantic States Upland and Western Upland cotton of 1-inch staple, were secured early in July, 1913. This cotton was stored at the Riverside and Dan River Cotton Mills, Danville, Va., where the experiments started on October 1. The Danville tests will be supplemented by additional experiments made on a certain quantity of the same cotton which has been sent to the textile department of Clemson Agricultural College, Clemson, S. C., and to the North Carolina Agricultural and Mechanical Textile School, at Raleigh, N. C.

The average difference in percentage of visible waste between Western Upland and Atlantic States Upland cotton was found to be between 1 and 2 per cent, taking all the grades into consideration. The differences are considerably greater in the lower grades than in the higher grades. The mill-waste figures have been checked up by hand separation of composite samples, and the figures from these experiments are consistent with those obtained from the mill.

Although the value of the visible waste from the various grades is not yet determined, it appears certain that the valuation figures for the waste of the two classes of cotton will be approximately equal, weight for weight.

Preliminary figures show the yarn from the two classes of cotton to be about equal in strength.

The mill waste in the experiments to date varies from about 4 per cent in Middling Fair to about 11 per cent in Good Ordinary, while the figures for the other grades are more or less consistent.

At the close of these experiments exhibits made from the material reserved at each stage in the manufacture will be made to accompany the full report.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



No. 63

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
March 28, 1914.

FACTORS GOVERNING THE SUCCESSFUL SHIP- MENT OF ORANGES FROM FLORIDA.¹

By A. V. STUBENRAUCH, *Pomologist and Horticulturist*, H. J. RAMSEY, *Pomologist in Charge of Fruit Transportation and Storage Investigations*, and LLOYD S. TENNY, *formerly Pomologist in Fruit-Transportation Investigations*; assisted by A. W. MCKAY, B. B. PRATT, C. S. POMEROY, K. B. LEWIS, G. M. DARROW, MARGARET CONNOR, and J. F. FERNALD, *of the Office of Horticultural and Pomological Investigations*.

INTRODUCTION.

The citrus-fruit industry of Florida is preeminently first among the agricultural and business interests of the State. According to the figures of the last United States census there were 3,864,514 orange trees in the State in the spring of 1910, 2,766,618 of these being of bearing age and 1,097,896 nonbearing. The yield of the 1909 orange crop, as given by the census of 1910, was 4,852,967 boxes, valued at \$4,304,987. From the best sources obtainable at the present time,² the citrus crop of Florida during the season of 1912-13 amounted to 28,428 carloads, or 8,125,465 boxes, of which approximately 5,769,079 boxes, or 71 per cent, were oranges; approximately 2,031,367 boxes, or 25 per cent, were grapefruit; the balance, of approximately 325,019 boxes, or 4 per cent, being tangerines, kumquats, and limes.

During the winter of 1894-95 there occurred in Florida two very severe freezes, which wrought great havoc in the groves of the State and permanently changed the character of the citrus industry. Present conditions date from that season to a great extent. According to Hume³ there were 5,055,367 boxes in the crop of 1893-94, and the output for the following year would doubtless have reached 6,000,000 boxes. Exceptionally low temperatures, interspersed with periods of warm, growing weather, proved fatal, however, and a large number of trees were either killed outright or had practically all of their bearing wood destroyed. Instead of 6,000,000 boxes, the crop of 1894-95 was reduced to 75,000, as a consequence. It will be seen, therefore, that so far as production is concerned, the Florida citrus industry is now just regaining the position which it held at the time of the freeze of 1895.

LOCATION OF THE FLORIDA CITRUS INDUSTRY.

Previous to the freeze of 1895 the citrus industry of Florida was largely centered in Lake, Orange, and Marion Counties. After the destruction or serious damage to a large number of the best groves in these sections some of the owners became discouraged and

¹ Report on harvesting, handling, and shipping experiments made on a commercial scale through seven shipping years, showing that decay can be materially lessened by greater care and the avoidance of mechanical injury to the fruit.

² These figures were furnished by the Florida Citrus Exchange.

³ Hume, H. Harold. *Citrus Fruits and Their Culture*. Jacksonville, Fla., 1904, p. 4.

either went north to engage in other enterprises or sought locations for their new groves farther south, where conditions were considered safer. Since many of the older groves have been reestablished, the industry has become widely scattered over the State. Plantings now extend in a narrow fringe along the east coast, from St. John County on the north to below Miami, in Dade County, and along the west or Gulf coast they reach from Citrus County almost to the southern boundary of Lee County. Extensive plantings extend diagonally across the State from Volusia County on the east to Hillsboro, Manatee, De Soto, and Lee Counties on the west, including large sections of Brevard, Orange, Lake, Sumter, Hernando, Pasco, and Polk Counties, in addition to those already mentioned. Sections in Marion, Alachua, Citrus, and Osceola Counties also are devoted to citrus fruits. Figure 1 shows a map of the State with the location of the citrus plantings indicated by shading.

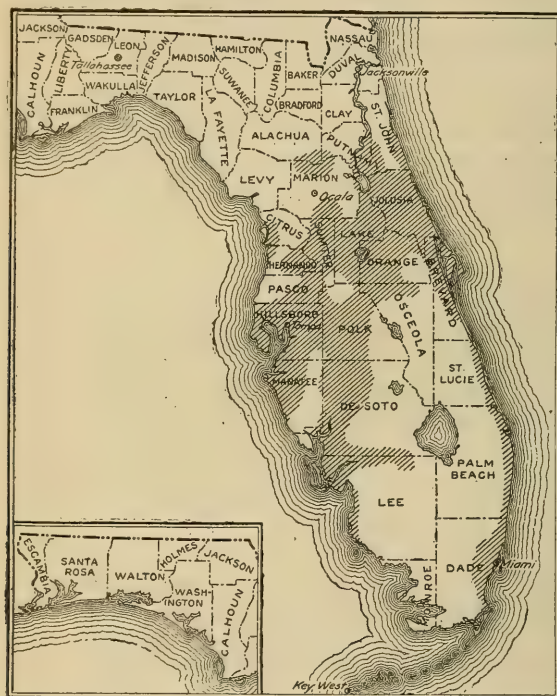


FIG. 1.—Map of Florida, with the location of the principal citrus plantings indicated by shading.

special effort was made to pack the fruit in an attractive manner and to have it reach the market without decay. At present, with the groves so widely scattered throughout the State, there is much less personal contact between growers, and the old neighborhood competition in the production of fancy fruit has largely disappeared. Although the industry has become better organized during the last few years, it is extremely difficult to make effective any association which represents so many diverse interests and whose members are so widely scattered. This situation has proved a great barrier to the introduction of better handling and marketing methods.

HISTORY OF THE FLORIDA CITRUS INDUSTRY.

It is believed that the orange was originally introduced into Florida by the Spaniards, who imported a few sour oranges and gave some of the fruits to the Indians. The seeds of these fruits, being distributed from village to village and finding congenial

citrus plantings indicated by shading.

The difficulties of handling and marketing crops of fruit produced in groves scattered over so wide a territory are manifestly greater than where the plantations are confined to a more restricted territory. Where groves are located comparatively close together, as was the case in many of the older citrus districts of Florida, a neighborhood competition is stimulated, especially in the production of clean, bright fruit of fine texture. There has probably never been a region where so many varieties of oranges have been developed and tested as in what, before the freeze, were the old neighborhood centers of production, or where more strenuous efforts have been made to produce fruit of fine texture and flavor. Moreover, a

soil and favorable climatic conditions in the hardwood forests and live-oak groves, where the tall native growth protected them from sun and radiation, grew up into seedling trees, and in time formed wild groves of immense extent throughout the northern and central parts of peninsular Florida.¹ Although sweet oranges were known in Florida before the Civil War, they were not considered of commercial importance because of the absence of transportation facilities. Commercial orange culture dates back to between 1865 and 1870, when the success of the trees along the banks of the St. Johns River began to attract attention to this industry as a good investment. As the profits were large from the first, many were thereby induced to engage in the business, and the industry gradually expanded until in 1895 the production had reached nearly 6,000,000 boxes.

Transportation problems and market conditions have changed considerably since Florida reached its highest point in citrus production before the freeze. First of all, the citrus industry of California has been largely developed since that time. Through the establishment of efficient transportation facilities and modern refrigerator-car service, the California growers have been enabled to distribute their fruit over practically every State in the Union. In the early days of the industry, the Florida orange growers did not have to meet the keen competition which has developed in recent years, and therefore the condition of their fruit upon its arrival in the market did not affect the selling price as much as it does at present. The market demand for Florida oranges was strong, and fair prices were usually obtained in spite of the presence of considerable decay. As the production increased just prior to 1894-95, less favorable prices were being received, and at the time of the freeze efforts were being made to extend the market both at home and abroad and to produce fruit of better keeping quality.

The formation during that period of the Florida Fruit Exchange may be considered as an effort among the growers to obtain better marketing conditions, induced, it is thought, by the necessity of improving the quality and condition of fruit in the markets. Although the Exchange failed to accomplish the special object for which it was created, it did prove that Florida oranges often failed to reach the northern markets in sound condition. Notwithstanding the general impression now current among growers that the decay of oranges was unknown before 1894, it seems to be well established that for many years the fruit has shown considerable waste.

A few reports taken from the current issues of the trade papers will serve to show that even at that time the decay problem was of considerable importance. In the issue of December 23, 1893, of "The Florida Despatch Farmer and Fruit Grower," under the Buffalo-New York fruit-sales letter, a statement was made which is characteristic of many others and serves to illustrate the wasted condition in which the fruit often reached the market. This report reads, in part:

Very sorry to report that the fruit is still coming forward in poor condition. . . . About 1,400 boxes, good and bad, mostly all of which showed more or less decay, averaged \$1.51.

Under date of December 2, 1893, the following report is given:

The dealers and handlers throughout the country are worn out with the constant labor of repacking, in the effort to save something out of the ruins of the decay, and to save the fruit from going bodily to the dump. Buyers are afraid to take hold, because they have no assurance of getting an article that will hold together until they can get rid of it.

Out of 19 telegraphic reports, 12 mention fruit showing decay, using such remarks as: "Both much decayed," "Some lots in very bad order," "Oranges mostly decayed," and "Very rotten." It will thus be seen that the conditions which are conducive to the occurrence of decay were present in the early days of the industry.

¹ Mead, Theodore L. The orange. Article in *Cyclopedia of American Horticulture*, 1901, p. 1154.

With the extension of the plantings consequent upon the reestablishment of the industry, and the resulting increase in production, existing conditions have been largely responsible for the improper handling of the fruit, which has been shown by later investigations to be the fundamental factor underlying the occurrence of decay. Many of the new groves established since the freeze have been planted on pine land, where it has been necessary to use heavy applications of fertilizers. Frequently the fertilizers have been selected with the purpose of producing large crops rather than fancy fruit, and this seems to have been at the expense of quality, thus partly accounting for the large proportion of rough and unattractive oranges now to be found in the Florida crop. The production of large quantities of rather coarse and uninviting fruit has in turn led to rough and careless handling, for, as a general rule, the more attractive the fruit the greater will be the incentive to handle it carefully when preparing it for shipment.

In addition to the freeze, unfavorable conditions have existed which have more or less discouraged many growers and which have led to the production of inferior fruit, with a correspondingly increasing tendency to place it on the market in a manner not conducive to the best results. The control of the white fly, which has spread over practically every citrus district in Florida, has been a serious problem. Fruit which has been rendered unattractive through the attacks of this pest presents one of the most discouraging problems which growers have to solve, for it is difficult to make workmen who pick, grade, and pack unattractive fruit realize the importance of careful handling. The sooty-mold fungus follows the attacks of the white fly, covering the leaves and fruit with a dense black growth which detracts greatly from the appearance of the oranges, and in order to prepare this smutty fruit for market, cleaning is absolutely necessary. The effects of the cleaning processes upon the carrying quality of the fruit will be described later.

The market demands high-grade, well-packed fruit. As long as the supply of a commodity does not equal the demand, a poorer grade or a less attractive package may yield satisfactory returns to the shipper. With keen competition, however, and markets well stocked with good, carefully selected fruit arriving in sound condition, the packer of a poor grade of fruit which frequently arrives in bad order is at a great disadvantage and suffers accordingly.

METHODS OF HANDLING THE FLORIDA ORANGE CROP.

The Florida orange begins to ripen in late October or early November, and the shipping season extends until spring, some growers of late varieties even holding their fruit on the trees until summer. Shipments are usually heavy during December, and in the past approximately 50 per cent of the crop has been shipped before Christmas. In fact, there has been a strong tendency to begin moving the fruit before it has reached full maturity. This practice has been stimulated because it frequently happens that these early shipments give satisfactory returns, and fruit moved at this time runs no risk of being frozen later in the season. The practice of placing on the market large quantities of green fruit of poor eating quality is very objectionable, however, and does not stimulate future consumption of the product.

During the past few years the tendency has been toward lengthening the marketing season. Instead of attempting to dispose of the bulk of the crop before the holidays, when a large proportion of the fruit has not reached full quality, the season has gradually been extended, so that Florida citrus fruits are now moved in large quantities until the first of April, and even later. The influence of these changed conditions upon the occurrence of decay and deterioration at the market end will be apparent in the later discussion of the occurrence of decay at different times during the shipping season.

PICKING THE FRUIT.

Harvesting methods.—In harvesting the orange, it is necessary to sever the fruit from the trees by means of clippers or shears, the common type being a sharp-pointed clipper, such as is illustrated on the left in figure 2. Various other types are also in use at the present time, two of which are shown in figure 2.

Since many of the orange trees in Florida are large, only a small proportion of the fruit can be reached from the ground. The ordinary straight ladder, placed directly against the tree, is in common use. In order to secure all of the fruit at the top or in the center of the tree, the picker must stretch over a considerable distance, and he is very liable to pull many of the oranges which he can not conveniently sever with his clippers. Worse than this, however, it has not been uncommon to see the fruit on the ends of the limbs shaken off and allowed to drop to the ground, later to be picked up and placed in the field boxes along with the fruit properly handled.

Over the picker's shoulder is thrown a basket or bag in which the fruit is placed as clipped. The picking bag is sometimes an ordinary grain bag or gunny sack holding about 30 pounds of fruit; formerly, some men used a specially constructed bag which fastened around the body and frequently held nearly enough fruit to fill one of the boxes. The canvas-covered basket shown in Plate I, figure 1, holds approximately half of a box of fruit. Another type of picking receptacle, illustrated in Plate I, figure 2, has a hinged bottom which may be let down when emptying the fruit. The most common bag now in use is one made of heavy canvas and open at the bottom, so that the filled bag can be placed in the box and the fruit allowed to roll out gently.

Field boxes.—The fruit is poured from the picking receptacle into a field crate or box. The box in general use is about 28 inches long, 12 inches wide, and 13½ inches deep, has a capacity of a little more than one packed box of fruit, and may or may not have a central partition. Both types are illustrated in Plate I, figures 1 and 2. The size of this box was established through the practice of buying large quantities of fruit on the tree at a fixed price per box. Originally this price was intended to be per "packed box," but since it is more convenient to keep the record of the fruit as it leaves the grove, this type of field box, which holds enough fruit to allow culling and still give the buyer a packed box of oranges, was developed. Other kinds of field boxes, some of which are superior to the old box, are in use to a limited extent. Plate II, figure 1, shows a type of grocer's delivery crate which some growers use for handling their oranges.

The boxes in common use are constructed of such heavy material and hold such large quantities of fruit that it is impossible to handle them with sufficient care. When loading them on the field wagon or unloading them at the packing house, or even when moving them about in the house, they oftentimes strike the floor with sufficient force to cause some of the fruit to bound out. The objection commonly raised to making boxes of lighter material is that the workmen will break them by rough handling, especially when throwing them off the wagon in the field. It is a question, however, whether the average laborer will not treat a lighter box more carefully than he will a heavy iron-bound one, which tempts him to see how roughly he can handle it.

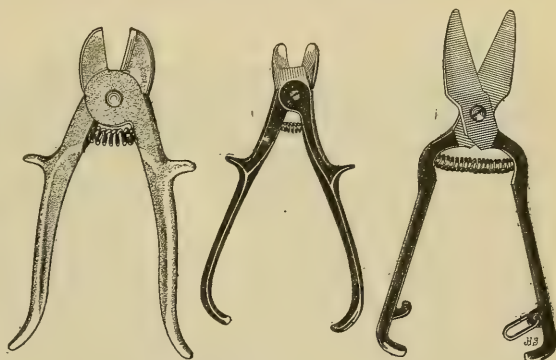


FIG. 2.—Three types of clippers used in picking Florida citrus fruits.

Plate II, figure 2 shows that the effort to make a field box strong enough to withstand "bucking" is not always successful. While it is difficult to estimate the amount of damage which may result from the use of such boxes, it is apparent that this is very great.

An enumeration of some of the injuries received in picking will be found under the discussion of the causes of blue-mold decay.

HAULING THE FRUIT.

The fruit is hauled from the grove to the packing house on ordinary farm wagons, which are often springless, or on specially provided wagons belonging to an association. The owner of the grove or the manager of the packing house sometimes personally superintends this transfer, but frequently it is done by contract with the owner of a livery stable. There is usually a fixed price for this service, one large contractor receiving 2 cents per box per mile, which is about the average of what is paid in different parts of the State. The drivers are often ignorant of the importance of careful handling, and their methods of loading and unloading are extremely crude and rough. It is not uncommon to see them sitting on boxes of fruit as they ride to the packing house. The haul may be long and over rough roads (Pl. III, fig. 1), some packing houses handling many boxes of fruit from groves 12 or 15 miles distant, or even farther. Ox teams are often used for such long hauls (Pl. III, fig. 2). It has even been the custom, in the past, to carry many oranges loose in the wagon box, the unloading being done with shovels or in other rough ways (Pl. IV, fig. 1). This practice has been done away with, however, as it is recognized that good results can never be obtained by such careless methods. Along with the numerous improvements which have been effected during the past two or three years in the manner of hauling fruit from the grove to the packing house, must be reckoned the State-wide movement for better roads.

PREPARING THE FRUIT FOR SHIPMENT.

Buildings and machinery.—Packing houses are usually located in villages and towns along the railroad lines or in places accessible to water transportation. Many boxes of fruit, however, are packed either openly in the groves or in houses located near the farm buildings and are then hauled to a shipping point. Little attempt was made until recently to build houses especially designed for packing citrus fruit. The average building usually had a capacity for handling not more than one car a day, very little machinery being used in the old houses and the boxes being made by hand, frequently in some place outside the packing house. This building generally consisted of but one room, the sizing machine being located in the center, a little below the main portion of the house, in what is called the "pit." One common source of trouble, even in the new-style houses, is the attempt to save floor space. The machinery may be so adjusted that the orange has to follow a long and complicated path, around abrupt angles, down gravity runs, and up unnecessary elevators, whereas in a majority of cases the same end could have been attained at less expense by means of a more simple arrangement. Simplicity should be the watchword in the adjustment of all packing-house equipment. Some houses have gone to the other extreme of doing practically all the work by hand, thus eliminating the expense of carrying belts and other automatic devices. The character of the workmen is then of fundamental importance, and it is doubtful whether, in the long run, hand work can be accomplished with as little injury as results from the use of properly adjusted, simple machinery.

Fruit which was clean and did not require washing was formerly poured into a hopper and rolled by gravity in front of the grader to the sizing machine. The latter was sometimes run by power, but more often it was treadled by the man who did the grading. As the oranges were sized they fell into different bins and from these were



FIG. 1.—EMPTYING ORANGES FROM A PICKING BAG INTO A FIELD CRATE, SHOWING AN INCORRECT METHOD, WHICH RESULTS IN THE SERIOUS BRUISING OF THE FRUIT.



FIG. 2.—FLORIDA FIELD CRATE WITHOUT A CENTRAL PARTITION AND ONE TYPE OF SMALL PICKING RECEPTACLE OPENING AT THE BOTTOM TO AVOID BRUISING THE FRUIT BY DROPPING.

PICKING RECEPTACLES AND FIELD BOXES FOR FLORIDA CITRUS FRUITS.



FIG. 1.—GROCERS' DELIVERY CRATES USED BY SOME GROWERS FOR HOLDING ORANGES.

This crate supplies maximum ventilation and has no sharp corners or projections to injure the fruit.



FIG. 2.—BROKEN FIELD CRATES.

The splinters, sharp edges, and projecting nails are common sources of serious injury to Florida citrus fruits.

TYPES OF FIELD BOXES FOR CITRUS FRUITS IN FLORIDA.



FIG. 1.—HAULING ORANGES OVER ROUGH ROADS ON WAGONS WITHOUT SPRINGS.
The jolting and jarring and the driver seated directly upon the fruit result in serious injury.



FIG. 2.—HAULING ORANGES BY TEAMS OF OXEN HITCHED TO SPRINGLESS WAGONS.
TRANSPORTING FRUIT FROM THE GROVE TO THE PACKING HOUSE
IN FLORIDA.



FIG. 1.—GRAPEFRUIT CARRIED LOOSE IN THE BED OF A SPRINGLESS WAGON AND PILED IN THE GROVE.

Note that the wagon driver is in the act of throwing fruit from the wagon to the pile.

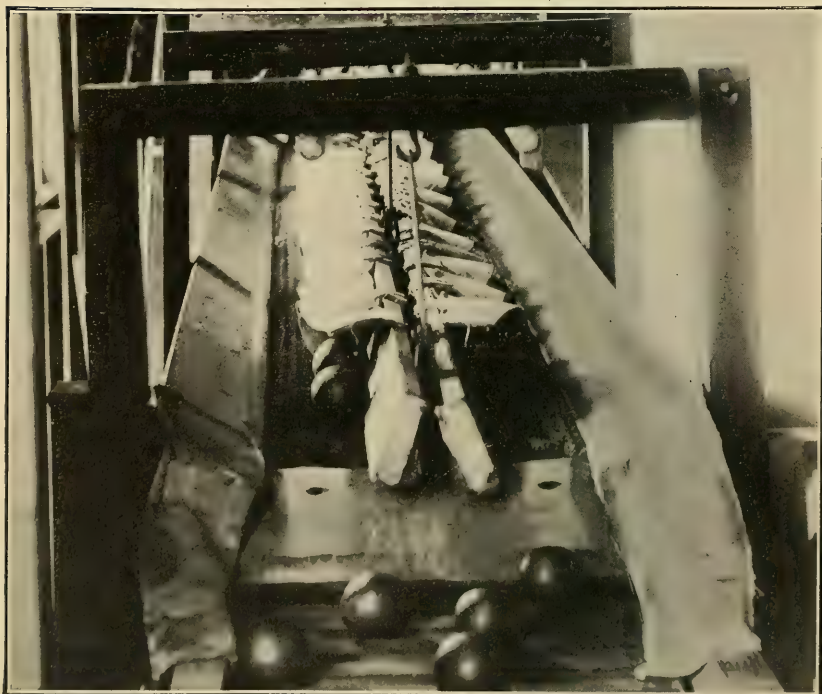


FIG. 2.—ONE TYPE OF ORANGE WASHER NOW IN USE IN FLORIDA.

packed out (Pl. V, figs. 1 and 2). In most of the houses at the present time the fruit is carried in front of the graders on canvas belts to the sizing machines, which are usually run by power. The majority of the packers now wish to ship their fruit as soon after picking as possible. Some, however, still keep it for a couple of days to wilt or "cure," as the process is called.

Cleaning.—During the past few years cleaning the fruit has become more and more necessary because of the spread of the white fly. At the present time probably 75 per cent of the Florida orange crop is cleaned either by washing or by the sawdust method. Until some method of controlling the white fly has been discovered, it will be necessary to continue these processes and even to extend them to a larger proportion of the fruit.

Various methods of washing are used, and many different types of washers are now in operation in the State. Some of the machines developed and used extensively in California have been installed, and other types have originated in Florida. The fruit is either dumped into a small hopper leading to a tank of water or is emptied directly into the water, and the cleaning process consists of passing the fruit, either while in the water or while still wet, over or between rapidly moving brushes, which remove the sooty coating from the skin (Pl. IV, fig. 2, and Pl. VI, fig. 1). A number of washers are used in which the cleansing is done by means of sponges or rags. After the fruit has been washed it is run through "artificial" forced-air blast driers or else elevated to drying racks (Pl. VI, fig. 2) and when dried is ready to be graded and sized.

Another method of cleaning citrus fruits, especially grapefruit, is with sawdust. Large horizontal cylinders are completely filled with fruit, a few pounds of wet sawdust are added, and the cylinders are then revolved for 8 or 10 minutes by hand or other power. The movement of the sawdust over the surface of the fruit rubs off much of the dirt and sooty mold. No drying is required after this process (Pl. VII, fig. 1).

Grading.—There are no set rules for grading oranges and grapefruit in Florida. As a rule, only two classes are made, "brights" and "russets," in addition to a poorer grade which is shipped to near-by markets. The bright fruit is that which is free from the effects of the work of the rust mite, a small mite which punctures the oil cells in the skin of the fruit, causing the surface to become brownish in appearance. The russet grade is composed of fruit more or less affected by the work of the rust mite. Fruit affected with melanose, a disease common in many sections, is also usually placed in the russet grade. The russetting due to the work of the rust mites is quite characteristic of the Florida orange and has been almost a trade-mark for the fruit, the general impression prevailing in the North that such oranges are a distinct variety grown only in Florida. Consequently, this grade frequently brings as much money as bright fruit. It has never been determined that the work of the rust mites affects the quality of an orange or grapefruit. The number of mites varies considerably in different localities and even in groves in the same locality, and when present they may be largely controlled by the use of sulphur sprays or by dry sulphur blown upon the trees.

A few packing houses in the State make more than two grades. The finest of the bright fruit may be packed as "fancy," or some of the brightest russets may be labeled "golden." There are no uniform rules in the State, however, and similar grades of fruit from different packing houses may be sold under different names. Moreover, all grading is without reference to the size of the fruit. As one man grades a car or more of fruit each day, the work can not be done very thoroughly. There is a strong tendency at present to establish more definite grades and to secure better methods of grading (Pl. VII, fig. 2).

The sizes of Florida oranges vary from 80 to 420 fruits in a box, some fruit occasionally falling outside even these wide limits. The common sizes are 126, 150, 176,

and 200 oranges to a box. When only two grades of fruit are made, a double sizing machine is commonly used, and both grades are sized at the same time (Pl. VIII, figs. 1 and 2).

The Florida grapefruits are packed with 28, 36, 46, 54, 64, 72, 80, or 96 fruits to the box, the most desirable sizes being 46, 54, and 64. The "Standards" vary from 54 to 80. Fruits packed 46 to the box and larger are known as "large off sizes," grapefruit being occasionally offered as large as 18 to the pack. This is more of a novelty than a commercial proposition, however. The "small off sizes" are those packed 96 to the box and smaller. Some of the regular orange-sizing machines can be adjusted for the sizing of grapefruit, but few of them are wholly satisfactory, on account of the variation in shape of the fruit.

Packing.—Many houses now employ girls and women as packers, although formerly the work was done almost exclusively by men, who were usually paid by the day. High-grade work is done on the average, and considerable care is taken to have each orange put in its place with a little pressure. This makes a firm pack and one which is smooth and of good appearance. The box is filled an inch or more above the top, and when the cover is put on pressure is used to bring the fruit at the ends even with the top of the box. A few shippers fill their boxes much higher than this, thereby making necessary considerable pressure in order to nail on the cover. This type of package, known as the "bulge pack," was developed to meet the buyers' demands for a full box of fruit on arrival in market. High packing is often an excuse for poor packing, however, since oranges which are laid in the box loosely and without pressure must be forced into place when the cover is nailed on, thereby increasing the liability of crushing the fruit in the top layers. A pack which is of medium height, with every orange firmly in place, is less liable to be injured in transit than is a high, loose pack, and the fruit will arrive in market with a more attractive appearance and will remain in good condition for a longer period.

The "nailer" takes the box after it is packed, and holding the cover across the fruit with both hands, he gives the box two or three sharp jolts upon the floor, first at one end, then at the other, before nailing it fast. Box presses are in use in a number of houses in the State. Whether the nailing is done by hand or with the aid of a press, care should be exercised to avoid injuring the contents of the top layer against the sides and ends of the box. Some pressmen have the habit of adjusting the covers after pressure has been applied by tapping the ends of the slats, but this scratches or rasps the fruit on top and serious injury sometimes results. The beveled ends, sides, and center pieces which are coming into general use are of great value in preventing injuries during the nailing operation.

The Florida shipping box for both oranges and grapefruit measures 12 by 12 by 27 inches, inside dimensions, and has an estimated weight of 80 pounds when filled. It is made with paneled heads, has sides of veneer in one piece, and is bound with three straps of birch or other wood. Wire hoops are now used extensively in place of the wooden straps. This makes a strong package, suitable for long-distance shipments.

Shipping.—More attention than formerly is now being given to loading the fruit in the cars. It has been the custom to stack the boxes loosely in the cars, those in the lower tier standing on end and the rest placed lengthwise on top. On account of the strength of the box and the comparatively short haul, the loading is done rather carelessly, very little bracing being used, and often none at all. Although it is not common for the boxes to reach the market in a broken condition, considerable injury in transit is liable with a load of this kind. The better method now coming into general use in Florida is to stack the boxes two tiers high on end, using a car strip across each row and bracing the load securely in the middle. This insures a minimum of broken boxes or other injury on arrival in market.

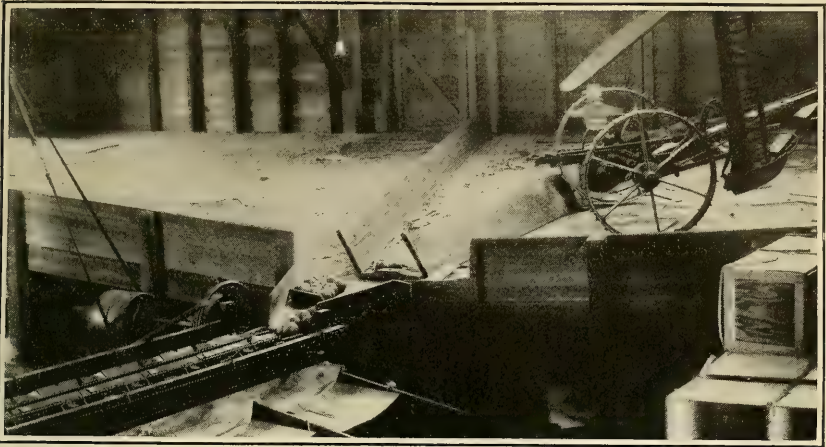


FIG. 1.—EXTREME TYPE OF LARGE HOPPER FORMERLY IN USE, THE SIZE BEING INDICATED BY THE SIZE OF THE MOWING MACHINE AT THE RIGHT.

The fruit is emptied from outside through trap doors in the background, a wagonload at a time. Serious injury is caused by bruising and by the twigs and other débris accumulating on the floor of the hopper.



FIG. 2.—ANTIQUATED MACHINERY FOR GRADING AND SIZING THE FRUIT.

Note that the sizing machine is being treadled by the grader. Note also the large hopper at the rear.

INTERIOR VIEWS OF OLD ORANGE-PACKING HOUSES IN FLORIDA.

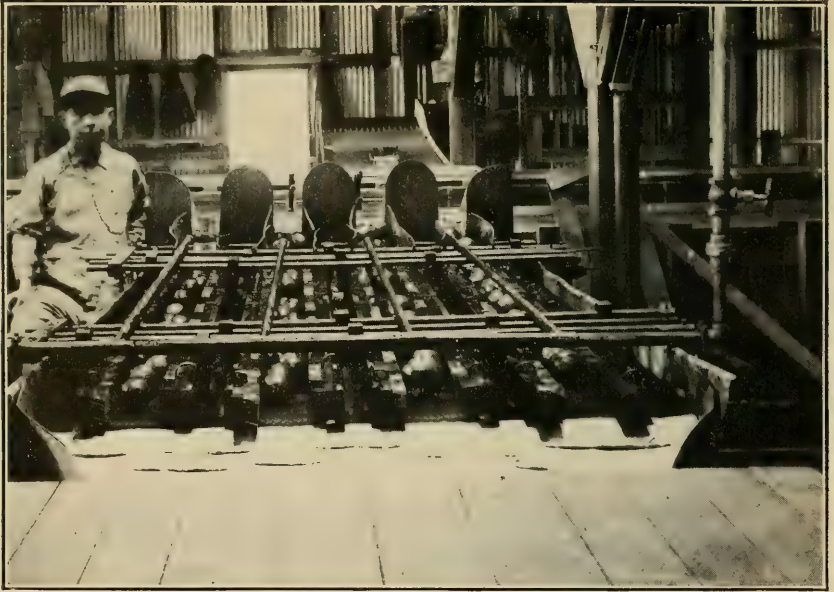


FIG. 1.—ONE TYPE OF ORANGE-WASHING MACHINE USED IN FLORIDA.

The fruit is always in sight as it passes through the machine.

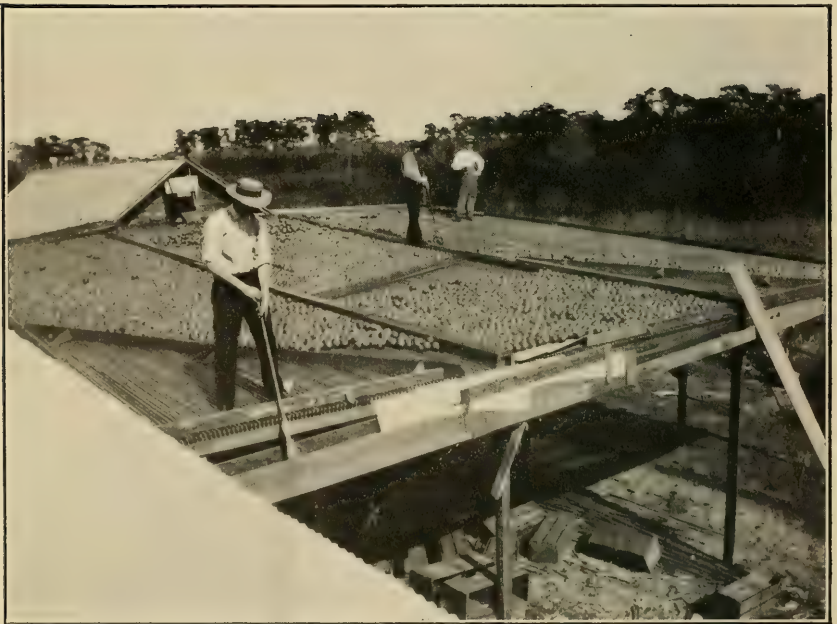


FIG. 2.—DRYING FLORIDA ORANGES IN THE SUN.

Serious injury follows the use of unprotected brooms, and bruising from rolling over and dropping through steep gravity runs.

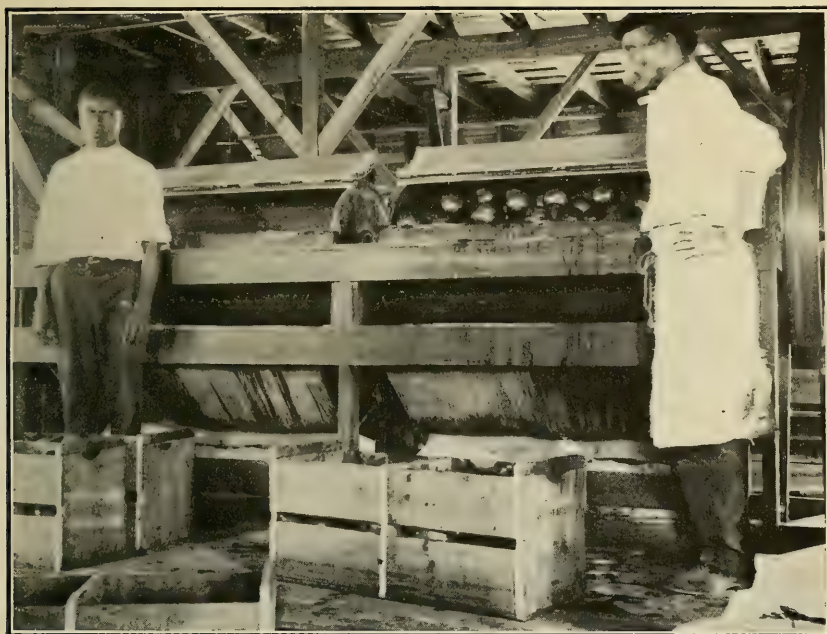


FIG. 1.—A SAWDUST CLEANER FILLED WITH GRAPEFRUIT.

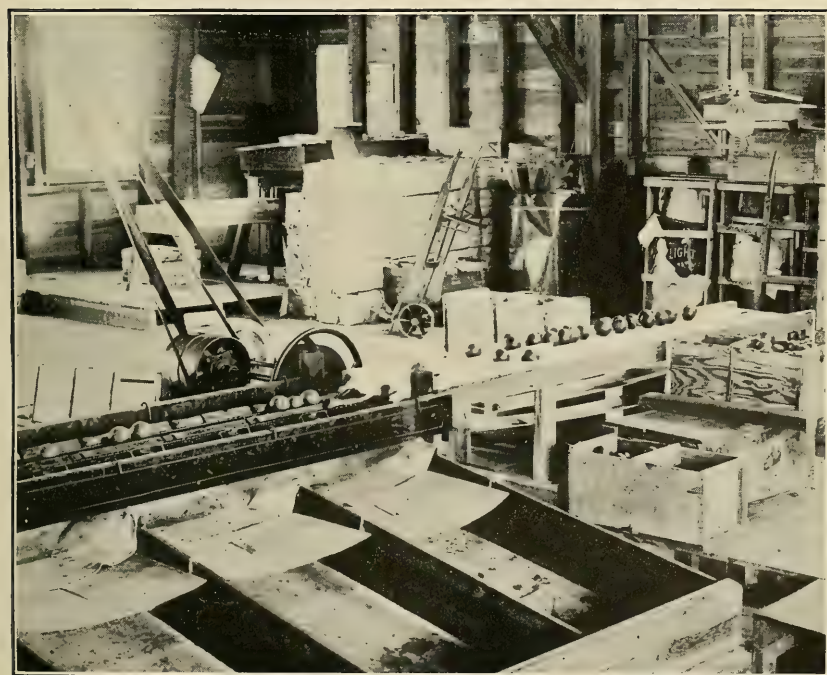


FIG. 2.—GRADING BELT BUILT BY THE BUREAU WORKERS FOR EXPERIMENTAL PURPOSES TO REPLACE THE LARGE HOPPER SHOWN IN PLATE V, FIGURE 1.

PACKING-HOUSE MACHINERY IN FLORIDA.



FIG. 1.—TYPE OF ORANGE SIZER, HOPPER, AND BINS USED IN THE OLD PACKING HOUSES IN FLORIDA.

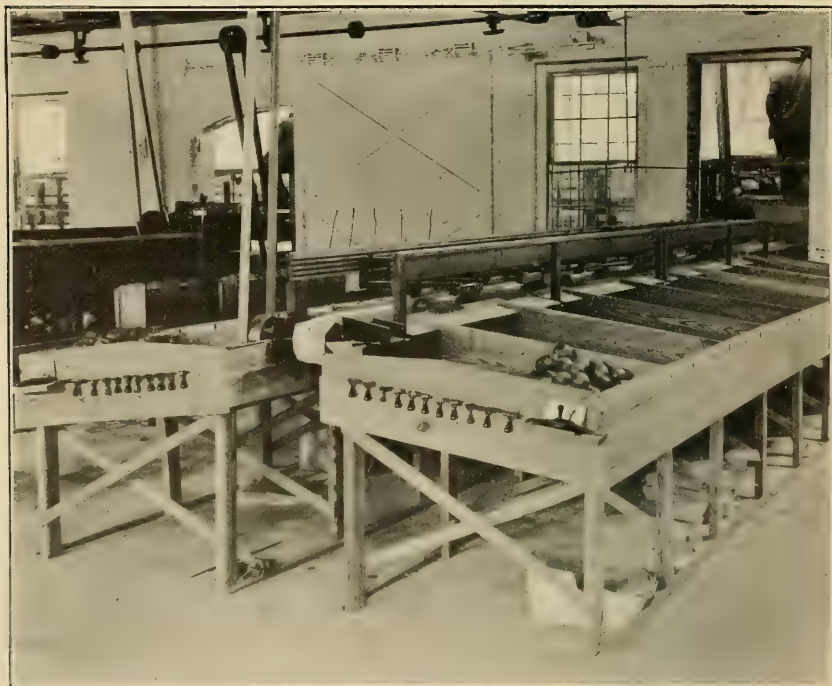


FIG. 2.—ONE TYPE OF SIZING MACHINE IN A MODERN PACKING HOUSE IN FLORIDA.

ORANGE-SIZING MACHINES.

The length of time in transit from central Florida to Philadelphia or New York varies from four days to more than a week. There are several routes by which fruit may be shipped to northern points. It may go "all rail" by freight, either in carloads or by local freight. Small consignments are sent by express to Savannah and from there by freight to their various destinations, and some fruit is shipped by water from both Jacksonville and Savannah. The rates to northern points vary somewhat by these different routes. Jacksonville is the basing point, and the "all rail" freight rate thence to Baltimore is 43 cents per box in carload lots. This rate to New York is 46 cents, to Boston 51 cents, to Pittsburgh 52 cents, and to Chicago 53 cents. The water rate from Jacksonville is 35 cents to New York and 40 cents to Boston. In less than carload lots the "all rail" freight rate to Baltimore is $47\frac{1}{2}$ cents, to Boston 59 cents, and to Chicago 97.2 cents. These rates apply on shipments moving through Jacksonville for points beyond. The rate is higher when the fruit is shipped to Jacksonville, the freight charges paid there, and the shipments rebilled to points beyond. In addition to the above charges the shipper has to pay the local freight from his shipping station to Jacksonville. This local freight rate per box is 15 cents from Orlando, 20 cents from Arcadia, and 26 cents from Miami.

During 1912-13 there were 321 boxes in the average carload. A few men shipped 400 or more boxes per car, but this practice should be discouraged. Such heavy loading leaves no space in which the air may circulate and affords a splendid opportunity for the development of decay in transit. The Florida car is smaller than the one used by the California shippers and should contain not more than 360 boxes. The inside measurements of the standard shipping car for oranges are 33 feet in length, 8 feet in width, and $84\frac{1}{2}$ inches in height. The minimum freight weight of a standard car of 300 boxes is therefore 24,000 pounds, reckoning each box at the arbitrary weight of 80 pounds. The freight rate is assessed per box, the average rate on citrus fruits shipped from Florida during 1912-13 being 65.7 cents per box of 80 pounds' weight. A car of oranges may contain boxes of oranges of all sizes, the fruit being generally loaded in the cars "orchard run," although some purchasers specify in advance the sizes desired.

Refrigeration and ventilation.—Prior to the season of 1912-13, nearly all of the shipments of Florida citrus fruits were handled under ventilation. A few of the late oranges, especially Valencias, have been shipped under refrigeration during the latter part of the season when the weather was warm either in Florida or while the fruit was in transit, but it is estimated that not more than 1 per cent of the shipments of citrus fruits were iced in any season previous to 1912. The conditions surrounding the citrus-fruit industry of Florida have been largely responsible for the lack of the proper facilities for the shipment of oranges under ice. Before the reorganization of the industry, following the introduction of modern handling and packing facilities, there was little or no opportunity to utilize refrigeration in transporting the citrus crop to market. A large proportion of the fruit was handled in local consignments to central points, such as Jacksonville, Fla., or Savannah, Ga., and at these gateway cities carload shipments were made up. In some instances the fruit was sent by boat to Jacksonville or Savannah and thence forwarded north by railroad. During the past three or four years this practice has changed to a very great extent, and at the present time only a small proportion (if any) of the shipments of Florida citrus fruits are assembled after local shipment at the central points mentioned. Packing houses equipped with modern appliances have been erected throughout the State. Full carloads are now made up at these houses and the fruit is shipped north direct from the point of production or packing. The opportunities for utilizing refrigeration have thus been increased, as the fruit can now be loaded direct into iced cars instead of being first shipped locally in unprotected "ventilator" or box cars.

The prevailing opinion among fruit growers and shippers formerly has been that Florida citrus fruits do not need refrigeration. Practically the entire crop is moved

during the winter and early spring months, when the prevailing outdoor temperature is low, so low at times that the problem has been to protect the fruit from freezing rather than to reduce its temperature by artificial means. During periods of extremely cold weather refrigeration may be a distinct disadvantage rather than otherwise. With the present refrigerator-car equipment, the insulation provided to keep the fruit cool during transit must also be relied upon to protect the fruit from freezing. This it does by retarding the cooling of the fruit and reducing its temperature very slowly, thus enabling the car to reach the market before the contents are actually frozen. It is easy to see that the length of time required to cool the fruit to an injurious extent depends upon (1) the outdoor temperature, (2) the efficiency of the insulation of the car, and (3) the temperature of the fruit at the time the car encounters extreme weather conditions in the North.

The present-day refrigerator car is only partially efficient during extreme weather. There are many types of refrigerator cars with varying insulation, but none are able to withstand extreme cold for any considerable length of time without the use of artificial heat, just as they are unable to keep the contents cool in hot weather without the use of ice. It follows, then, that under ordinary conditions during cold weather fruit which has been cooled by the use of ice during the early part of the trip from Florida will be more liable to injury from freezing than fruit which has not been so cooled before it is subjected to extremely cold weather. The appreciation of this point is of great importance in discussing the refrigeration of Florida oranges, because a very large proportion of the crop is moved during periods of excessively cold weather in the North, although the temperature in Florida may be sufficiently high to warrant the use of ice at the beginning of the trip.

The investigations of the Bureau of Plant Industry have amply demonstrated that Florida oranges may be transported to market under ventilation with a minimum loss from decay, even during periods of warm and humid weather, if sufficient care is used to preserve the skin of the fruit in a sound, unbroken condition. None of the experimental shipments commented upon in this paper were refrigerated. The use of refrigeration during transit to market must not be considered as a means to offset the effects of rough or careless methods of handling. Icing can not permanently prevent deterioration. The low temperature only temporarily arrests the development of the decay fungi. As soon as the fruit has been unloaded in market it warms up, and decay develops very rapidly if a considerable number of the oranges have been injured by careless handling. As a result such fruit soon gains a reputation for very poor market-holding qualities. It is as important to have the fruit reach the consumer in good condition as it is to have it arrive in the market sound.

A considerable number of shipments were iced during the season of 1912-13, especially during January and during a later period of warm, humid weather, when heavy decay developed in nearly all shipments. It is safe to say that the number of cars handled under refrigeration during this season was greater than during all previous seasons together. Many of the shippers claim that they have been able to place the fruit on the market in much better condition when shipped under refrigeration than when shipped under ventilation only. This conclusion is based upon a comparison of iced and noniced shipments. It is probable, however, that the comparison was not always fair, for the reason that no systematic study was made of the behavior of fruit of the same grade and quality under the two systems of shipment. Nevertheless, the general opinion prevails among growers and shippers that icing has resulted in material benefit to the fruit and has yielded increased returns. Refrigeration, therefore, bids fair to become an important factor in the handling and shipment of the Florida citrus crop.

During the past season, with its periods of excessively high decay, the Florida Citrus Exchange strongly urged its members to move their fruit north under refrigeration. The recommendations of the exchange officials, in brief, provided (1) that the

ice should be put in the tanks 24 hours before loading the fruit, and preferably 48 hours previous, in order to properly cool the cars; (2) that the boxes of oranges should be stacked near to the car and when the doors were opened the loading should commence immediately and not consume more than one hour; (3) that the doors should then be tightly closed and the car moved forward immediately. Since the refrigerating rates are per car and not per box, some growers loaded the cars very heavily this past season, shipping 400 or 500 boxes per car, in order to reduce the refrigerating charge per box. This left no room for ventilation or circulation of air, and as a result decay was heavy, especially in the top tiers. Boxes should not be loaded more than 2 tiers high and no car should contain more than 360 boxes. These may be loaded 6 rows across, 30 boxes long and 2 tiers high, on end.

Many refrigerator cars were shipped under one-half icing during 1912-13. When the fruit was very soft or from groves known to be diseased, full icing was found to be necessary. Table I gives the refrigerating rates for half icing from Florida to various points throughout the United States, these being in addition to the regular rates for transportation. When the entire ice bunker is filled, the charges are increased 50 per cent above those for half-bunker icing. For example, when the half-bunker rate to New York is \$50 per car, the full-bunker rate is \$75.

TABLE I.—*Rates per car for half icing from Florida to points in the United States, season of 1912-13.*

To southern points.		To eastern points.		To northern and western points.	
In State of—	Rate.	From Jacksonville.	Rate.	In State of—	Rate.
Georgia.....	\$35.00	Taking rate of—		Ohio.....	\$50.00
Alabama.....	40.00	43 cents per box.....	\$45.00	Indiana.....	50.00
Tennessee (except to Chattanooga).....	45.00	44 cents per box.....	45.00	Michigan.....	55.00
To Chattanooga.....	40.00	46 cents per box.....	50.00	Illinois.....	50.00
Kentucky.....	45.00	48 cents per box.....	45.00	Wisconsin.....	55.00
Mississippi.....	45.00	50 cents per box.....	50.00	Missouri.....	55.00
Texas.....	62.50	51 cents per box.....	55.00	Nebraska.....	55.00
South Carolina.....	35.00	52 cents per box.....	50.00	Kansas.....	55.00
North Carolina.....	35.00	53 cents per box.....	55.00	Colorado.....	62.50
Virginia (as to Lynchburg, Norfolk, Richmond, Roanoke, and Portsmouth).....	45.00	55 cents per box or higher.....	55.00	Minnesota.....	55.00
				Iowa.....	55.00

MARKETING THE FRUIT.

Noncooperative buyers.—Most of the Florida citrus fruits have been handled on the market by fruit buyers and speculators. Large quantities have been bought on the trees, either in bulk or at a fixed price per box, by local buyers who own packing houses in near-by towns. There are many such buyers, and, although very few of them are growers, they purchase enough fruit each year to pack and ship thousands of boxes. The largest part of the Florida citrus crop has been handled in this manner in recent years, the picking and hauling being done under the direction and at the expense of the buyers. These men have regular customers to whom they make shipments, and they also consign large quantities of fruit to commission houses. If a grower desires to pack his own fruit, he may be able to sell it before shipping it, but usually he consigns the cars to a commission man whose agent has solicited his trade. If the grower is doing business with a reliable firm, the success of this method depends largely upon having a good grade of fruit which is packed in an attractive manner and reaches the market in sound condition. Since most of the commission houses operating in Florida are located in the larger northern and eastern cities, the heavy shipments of fruit to these points often cause the market to be glutted with Florida oranges.

Several large selling agencies are now operating in Florida and are handling much of the citrus fruit. These firms may or may not be directly concerned with the grading and packing of the fruit. Although in a few instances they control this portion of the work almost entirely, and so are able to offer for sale large quantities of fruit of a rather uniform grade, their primary aim is to handle for the packers all matters pertaining to the sale of the crop. They claim to be able to keep a closer watch on the markets and on general trade conditions than an individual grower or packer can possibly do, and, by means of competent sales agents throughout the country, to be able to control the distribution of the product so as to avoid gluts and the resultant low prices. Their selling charge may be a flat rate per box, but more often the business is conducted on a percentage basis.

Florida Citrus Exchange.—The movement for cooperative marketing, begun during the season of 1909-10, gained considerable headway among the citrus fruit growers of the State and resulted in the formation of the Florida Citrus Exchange. The organization was modeled after the California Fruit Growers' Exchange, which has been successfully packing and marketing a large percentage of the citrus fruits of California for a number of years. During its first season (1909-10) the Florida Citrus Exchange handled more than 1,000,000 boxes of fruit.

The Florida Citrus Exchange is composed of a number of cooperative associations throughout the State. These are made up of individual growers who form a corporation, build a packing house, elect a manager, determine the grades under which their fruit is to be shipped, and attend to all the business directly connected with the harvesting, packing, and shipping of the fruit. The cooperative packing houses located in any one of the several citrus districts of the State unite to form a subexchange, whose manager has charge of the larger business interests of the houses in his district, keeping in close touch with the central offices of the exchange, and advising with them regarding the qualities and grades of fruit in the various cars shipped, the methods of packing employed, and all other matters regarding which a selling agency should be well informed. A union of the various subexchanges forms the Florida Citrus Exchange, which has its headquarters at Tampa. This is an incorporated body, with a board of directors and officers for carrying on the business of marketing the product. Representatives of the exchange, who are paid on a salary basis, are located in the various trade centers and have charge of the sale of the fruit.

The fruit of the individual grower may be handled in the packing house as a separate account; or it may be packed under certain grades, a record being kept of the number of boxes of each grade made from the fruit of that grower, whose identity is lost as soon as this amount has been recorded. When the latter plan is followed, the season is generally divided into periods of several weeks in length, called pools, the receipts for all fruit shipped during each period being averaged by grades. The individual grower receives a pro rata share of the proceeds, determined by the quantity of each grade of fruit which he has delivered at the packing house during that pool. In a few packing houses one pooling period extends over the whole season, and the only average made is based upon the proceeds of the entire crop.

KEEPING QUALITY OF FLORIDA ORANGES.

The keeping quality of the orange is naturally good. Since the life processes of the fruit continue after it has been severed from the branch, there is a prolonged period during which an uninjured orange remains sound and free from all decay. Ultimately, when the life span has been run, the tissues die and decay follows even in uninjured fruits. The delay is long enough, however, to allow the average fruit to be packed and placed on the market and to reach the consumer in sound condition.

HEAVY LOSSES FROM DECAY IN COMMERCIAL SHIPMENTS.

The losses from decay during transit have been very heavy in the commercial shipments of fruit, and the experimental work of the Bureau of Plant Industry was undertaken in Florida in response to the many requests for advice and assistance which came to the Department of Agriculture. It is difficult to estimate what the actual loss from this cause has been during past seasons. Several reliable commission men who handle large quantities of Florida oranges each year have stated that averaging the good with the bad years probably 10 per cent of the fruit decayed before reaching the consumer. Experimental shipments made under the direction of this bureau indicate that the loss may have been fully as heavy as this.

Since Florida's orange crop averages 4,000,000 or 5,000,000 boxes per year, the decay of 8 or 10 per cent of this fruit entails an annual financial loss of at least half a million dollars. Ten per cent of 4,000,000 boxes amounts to 400,000 boxes, on which the picking and packing charges have been paid, with approximately \$50,000 spent for box material alone. The freight charges represent something like \$200,000; and these amounts, together with the commission charges, the value of the fruit discarded, and the cost of repacking what is left, bring the total loss high enough to seriously endanger the welfare of the industry.

REPUTATION INJURED BY DECAY IN TRANSIT.

Unfortunately, the financial injury is not confined to the fruit actually decayed. It is impossible to estimate the loss which has resulted to the industry from the bad reputation which Florida fruits have gained in the trade. While it is difficult to discover how far the low prices occasionally received have been due to this cause, many fruit handlers in northern markets condemn very strongly the poor keeping quality of the Florida orange and willingly admit their intention of using fruit of better keeping quality if they can obtain such from other points. The situation of the Florida orange grower would be critical indeed if it were not for the fact that fruit handled carefully shows so much less decay than does fruit picked and packed under careless commercial conditions.

HISTORY OF THE DEPARTMENT WORK IN FLORIDA.

Investigations by the Department of Agriculture, having in view the discovery of the factors underlying the successful shipment of oranges from Florida to northern markets, began during the season of 1907. The work, which was planned along lines similar to those followed in the California investigations, included the determination of the character and type of handling employed in the various operations of preparing fruit for shipment and the discovery of the relationship between present methods and the occurrence of decay. The object of the work of the department was to suggest changes in the industry which should reduce the immense annual financial losses of the Florida growers by enabling them to market their fruit in sound condition.

The first researches in Florida were conducted by Mr. L. S. Tenny, who devoted his attention to an inspection of the work done by various picking crews and individual pickers, as well as to the character of work being done in the packing houses. It required only a short time to indicate that what had previously been found to be the case in California was also true in Florida, viz, that the fruit was receiving considerable injury in the course of its preparation for shipment. Conditions were, if anything, somewhat more exaggerated, owing to the fact that the thin-skinned, juicy Florida orange is of a more tender type and is more easily injured than the bulk of the oranges grown in California. It is safe to say that the kind of handling which would enable the California orange to go through the various picking and packing operations without injury is not safe for the Florida product. The importance of avoiding dropping or puncturing by long stems is most urgent when dealing with

thin-skinned, juicy fruit. The necessity of handling with extreme care so perishable a product as the Florida orange can not be too strongly emphasized.

After the determination of the character of work being done and the discovery that considerable injury was being inflicted on Florida fruit, the investigations were so planned as to determine whether it was practicable to handle the fruit with sufficient care to prevent injury. At first demonstrations corresponding to those carried on in California were made in the packing houses, using fruit selected for soundness and similar lots showing injuries of various kinds. The effects of dropping the fruit and of washing it to remove sooty mold were also demonstrated. These lines of work proved conclusively that blue mold develops wherever the skin of the orange is injured in any way, and that dropping is followed by serious decay, especially when the fruit falls into a receptacle containing dry twigs, gravel, splinters, or other matter rough enough to bruise or puncture the skin.

After the packing-house demonstrations, showing that sound, uninjured Florida oranges are not affected with blue-mold decay, shipping experiments under commercial conditions were undertaken. These experiments consisted of forwarding boxes of fruit of known history to Washington, where the percentages of decay were carefully determined on the day of arrival and after one, two, and three weeks, the fruit meantime being held under ordinary open-market conditions.

These experiments were followed during five successive seasons, thus enabling the investigators to determine the effect of seasonal influences. The data obtained during 1910-11 and 1911-12, when the work was undertaken on a more extensive scale than in the former seasons, corroborated the early results without exception, and the carrying quality of the Florida orange when packed and shipped in sound condition was proved to be as good as that of the California product. An injured orange, whether grown in California or in Florida, will decay whenever the conditions for the development of blue mold are favorable. A sound orange in good, healthy condition, whether grown in California or in Florida, is able to resist blue-mold decay.

BLUE-MOLD DECAY OF THE ORANGE.

Indications of decay.—The characteristic appearance of the orange decayed by blue mold is too well known to need description. Every handler of citrus fruits knows blue mold, which is by far the most common form of decay. The grower frequently sees it in the oranges hanging upon the trees, when the fruit has split or has been injured by thorns or twigs. He finds it in the fruit which has dropped to the ground. The packer sees it in the cull pile or in the boxes of fruit left standing in the house for a few days. The receiver of the fruit finds the decay as the boxes are opened, and frequently he smells it before removing the covers.

The first indication of decay is a small area of soft tissue at some point on the surface of the fruit. This increases rapidly in extent if the weather is moist and warm, and within a day or two a bluish or greenish spot develops. If weather conditions continue favorable, the entire fruit is rotted within a few days, and the surface is generally coated with a bluish or greenish blue mat or powdery covering.

BLUE-MOLD FUNGUS.

Blue-mold decay is caused by the growth of a minute organism within the tissues of the fruit. Laboratory experiments have shown this organism to be a fungus of the genus *Penicillium*, which includes the familiar blue mold or mildew on bread, on the surface of canned fruit, and on other vegetable matter. Growth takes place within the orange, the bluish mat on the skin being composed of the fruiting bodies made up of chains of spores, massed together in great numbers. The fungus is spread by means of these spores, which, like the seeds of many higher plants, germinate and grow as soon as they find lodgment under conditions favorable for their development. They

require heat and moisture, and when these are present growth proceeds at a very rapid rate. The blue-mold fungus has not the power to penetrate the sound living tissue of a well-grown fruit; hence, there must be a break or an abrasion of some kind in the skin, through which the disease may find an entrance. When growth has once started, even in a small way, the fungus is capable of killing the surrounding tissues and thus producing material on which to grow. This process continues until the entire fruit is destroyed. If, therefore, a fungous spore is present and lodges in an injured spot, the initial step toward decay has been taken, and if the temperature and moisture conditions during the next few days are favorable, the development of the fungus proceeds rapidly and the orange is almost sure to rot. Many experiments have been made in California and Florida packing houses in placing spores on fresh injuries, and, without exception, the characteristic decay has resulted. On the other hand, large quantities of fruit have been held under weather conditions most favorable to the development of decay, and the results prove that fruit which has been so carefully handled as to preserve the skin in an uninjured condition shows practically no decay even when the surface has been purposely covered with spores. The development of decay is most rapid during warm, moist weather, fruit packed during a cool, dry period frequently reaching the market without much waste even though injuries are present. Under changed atmospheric conditions, the same fruit may arrive in a badly decayed condition. During an average Florida winter there are usually periodical warm spells. Reports of general heavy decay at the market end can almost without exception be traced to fruit packed and shipped during these warm periods.

With this understanding of the nature and cause of the most common form of decay, it becomes easy to see how the harvesting and handling methods may have an important bearing on the keeping quality of the fruit. If these are such as to break the skin or injure the orange, even slightly, favorable conditions for the development of blue-mold decay exist and such decay is almost certain to result, as observation has shown that the spores of the blue mold are present practically everywhere. It is safe to say that most of the decay occurring in Florida oranges while in transit is due to blue mold. There is some loss in transit from decay due to other forms of rot, but this is usually very slight as compared with the loss from blue mold.

CAUSES OF BLUE-MOLD DECAY.

Since the principal means of securing oranges of good keeping quality is by eliminating mechanical injuries to the fruit, the occurrence of decay is therefore closely connected with the handling methods in use in the grove and packing house.

Thorn punctures, which are made while the fruit is still on the tree, are among the first injuries to which citrus fruits are subjected. These are generally unavoidable, as during every wind storm a certain percentage of the fruit is injured by being blown against thorns. The puncturing which occurs when the fruit is being picked may be prevented, however, although it is frequently difficult to handle the oranges with sufficient care to avoid pressure against thorns or dried twigs when these are present in large numbers. Fruit is often bruised when the ladder is placed carelessly in the tree or when the sack is allowed to strike or is pressed against the branches or ladder. (Pl. IX, figs. 1 and 2.) Moreover, filling the field boxes so high that the fruit projects above the top will result in crushing the oranges when the boxes are stacked one on top of another. The oranges may be bruised on their way from the grove to the packing house by being jolted over rough roads in springless wagons. The driver of each wagon should be given a specially prepared seat and not allowed to sit upon the fruit.

Among the most common forms of injury may be mentioned scratches made by the finger nails of the pickers and packers, each of whom should be required to wear gloves. It is comparatively easy for packers, especially if their finger nails are long,

to seriously injure a large percentage of the oranges which they handle. Some packers also do a great deal of harm by dragging the oranges around in the bins and by tossing the off sizes into the neighboring bins. Abrasions due to the presence of gravel, twigs, splinters, protruding nails, or other foreign matter in the picking receptacles, field boxes, or packing bins may have far-reaching consequences.

Bruises caused by dropping the fruit in the various stages of picking or packing have been found to cause serious loss from decay. There are a number of places where oranges may be greatly damaged by dropping. First of all, the picker may toss them carelessly into his picking basket or bag. Careless pickers frequently throw the oranges into the open receptacle by means of a shove with the clippers, the fruit sometimes falling as far as 3 or 4 feet. Serious damage may also result from emptying the fruit roughly into the field box. Plate I, figure 1, shows how the bag or basket may be held too far above the box and the fruit allowed to fall too great a distance. In case the bottom of the box is covered with twigs or small pieces of dirt the injury is greater. A sack which opens only at the top and from which the fruit must be poured into the boxes is likely to cause severe damage because of the bumps to which the fruit is subjected. Usually no greater care is observed when emptying the fruit into the field box and from that into the hopper of the washer, grader, or sizing machine. The washing machine provides excellent opportunities for the infliction of mechanical injuries and for infection from dirty water. This phase of the subject will be discussed later.

Decayed fruit and trash should not be left in the boxes or allowed to accumulate on the floor and under the packing bins. The slightest breeze will scatter great quantities of blue-mold spores from these rotted oranges over all the fruit in the house. A clean, well-lighted packing house greatly diminishes decay by reducing the chances of infection. It has a beneficial influence on the workmen as well, offering a great incentive to better work. Moreover, a clean packing house is a good indication of the character of work being done throughout and indicates whether genuine efforts are being made to improve the methods of handling.

The hopper into which the fruit is emptied has always been the source of much injury to citrus fruits in Florida. In the old style of packing house, existing before the work of the Bureau of Plant Industry was begun, the hopper was frequently large enough to hold a wagonload of fruit. Few, if any, of these are now in use. Even the more desirable small hopper was constructed with such a steep gravity run that the fruit was subjected to a severe bump on reaching the bottom. In going through the machinery or over the grading table other chances for injury occurred, and the final drop into the packing bin was sure to add several bruises. The desirable hopper has padded sides and allows the fruit to be emptied gradually by means of moving belts, which carry the fruit to the washing machine or grading belt; it is not necessary for the fruit to fall by gravity at any stage of its journey.

The most serious form of injury, however, is made by the clippers in removing the fruit from the tree. These clipper cuts are not as prevalent in Florida oranges as was found to be the case in the California fruit, for the reason that the Florida oranges are round and do not have the depression at the stem end which exists in the Washington Navel. Nevertheless, enormous damage has been done to the Florida fruits either by cutting the skin near the stem end when severing them from the branch or by puncturing them with the points. It is essential to have the ends of the clippers rounded or blunted in order to eliminate the possibility of piercing the fruit.

The presence of long stems on the oranges may be reckoned as equally disastrous. For this reason, in determining the character of work being done by a picking crew or individual picker long stems are included as imperfections. A long stem is just as serious, if not more dangerous, than an orange which has been injured in some way. The latter decays, but this rot seldom affects a neighboring orange; whereas a long stem has ample opportunity to injure a number of fruits in their progress from the tree

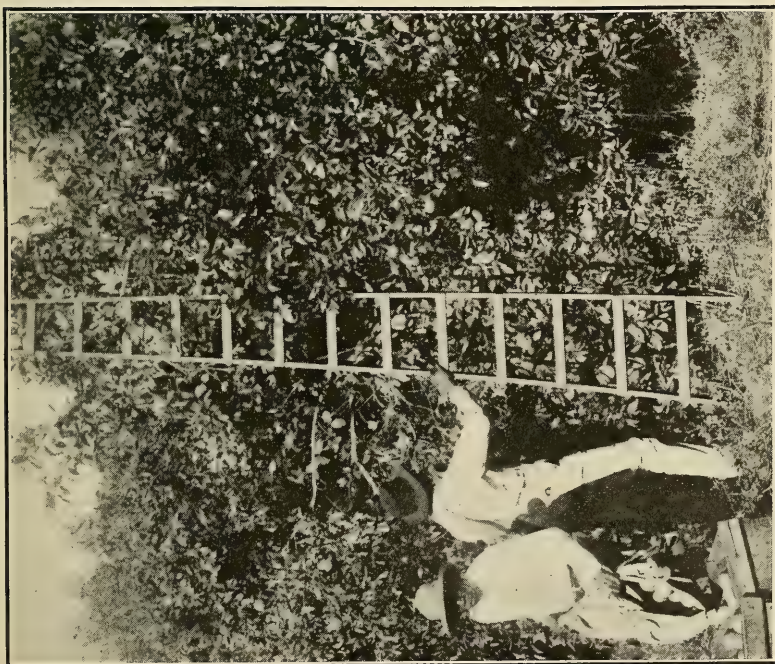


FIG. 1.—LADDERS PLACED CARELESSLY IN THE TREE ARE VERY LIABLE TO CAUSE INJURY TO THE FRUIT.

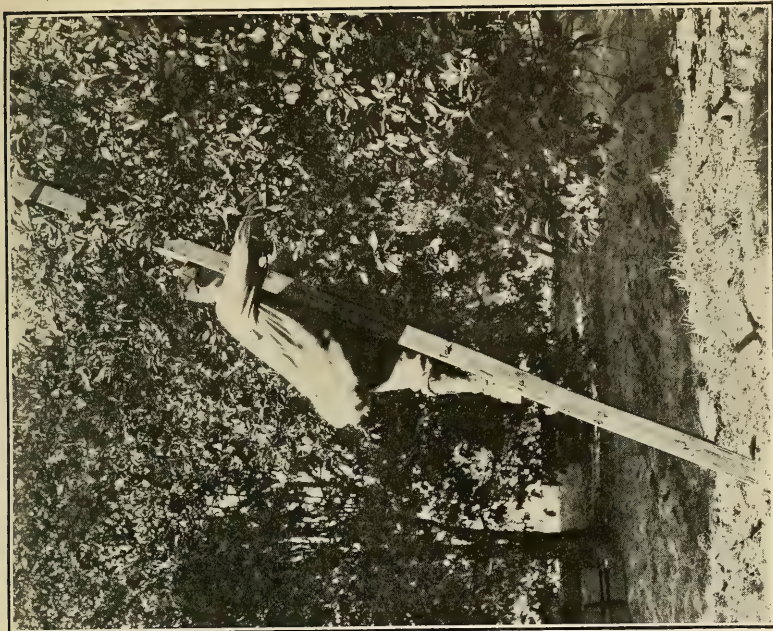


FIG. 2.—WHEN THE FRUIT IN THE SACK IS PRESSED AGAINST THE LADDER THE EFFECT IS ALMOST CERTAIN TO BE INJURIOUS.

PICKING ORANGES.



FIG. 1.—OLD PACKING HOUSE IN FLORIDA.

Showing a water tank made of an old wine cask and a pile of field boxes 90 per cent of which were broken or splintered.



FIG. 2.—OLD PACKING HOUSE IN FLORIDA.

Showing the method of emptying the fruit into the hopper from outside.

TYPES OF OLD PACKING HOUSES IN FLORIDA.



FIG. 1.—A ONE-STORY COMMODIOUS BUILDING CONVENIENTLY ARRANGED FOR HANDLING CITRUS FRUITS.

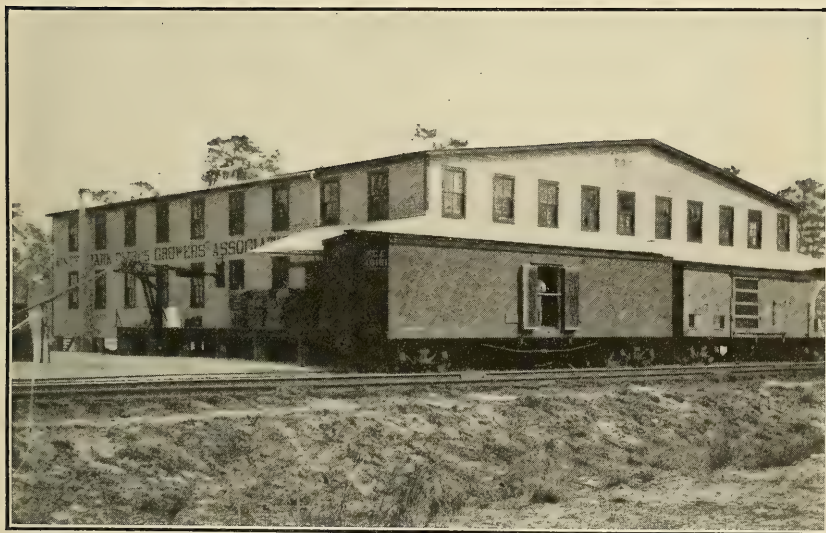


FIG. 2.—A TWO-STORY BUILDING WITH EXCELLENT FACILITIES FOR PACKING AND SHIPPING CITRUS FRUITS.

EXTERIOR VIEWS OF MODERN PACKING HOUSES IN FLORIDA.



FIG. 1.—AN OLD BUILDING FORMERLY USED FOR PACKING CITRUS FRUITS.

Note the crudeness of arrangement, the boxes of grapefruit stacked outside, and the many broken field crates.



FIG. 2.—THE MODERN BUILDING WHICH HAS REPLACED THE ONE SHOWN IN FIGURE 1.

ANTIQUATED AND MODERN TYPES OF FRUIT-PACKING HOUSES IN FLORIDA.



FIG. 1.—PACKING CITRUS FRUITS IN A POORLY LIGHTED AND OVERCROWDED ROOM.

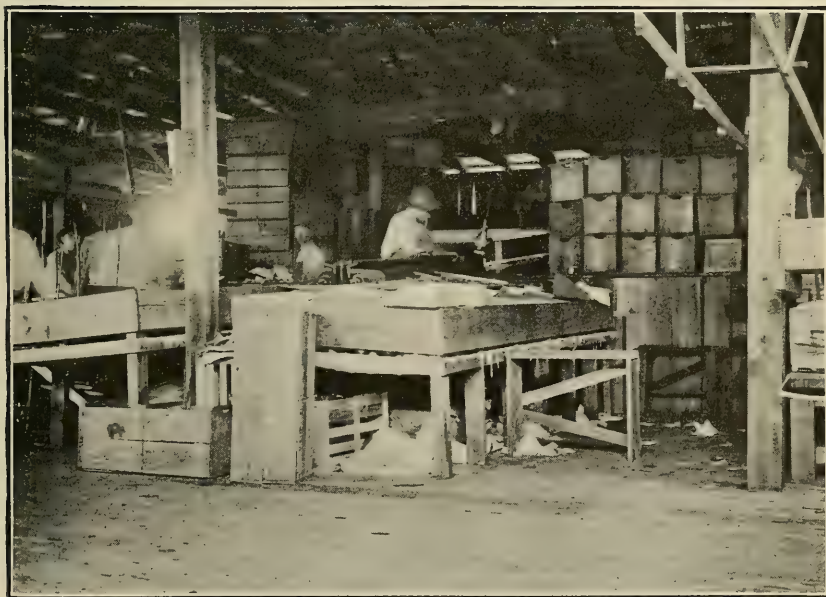


FIG. 2.—GRADING CITRUS FRUITS BY LANTERN LIGHT AT MIDDAY.

INTERIOR VIEWS OF TWO OF THE OLD PACKING HOUSES IN FLORIDA.



FIG. 1.—CORNER OF A WELL-LIGHTED BUILDING.

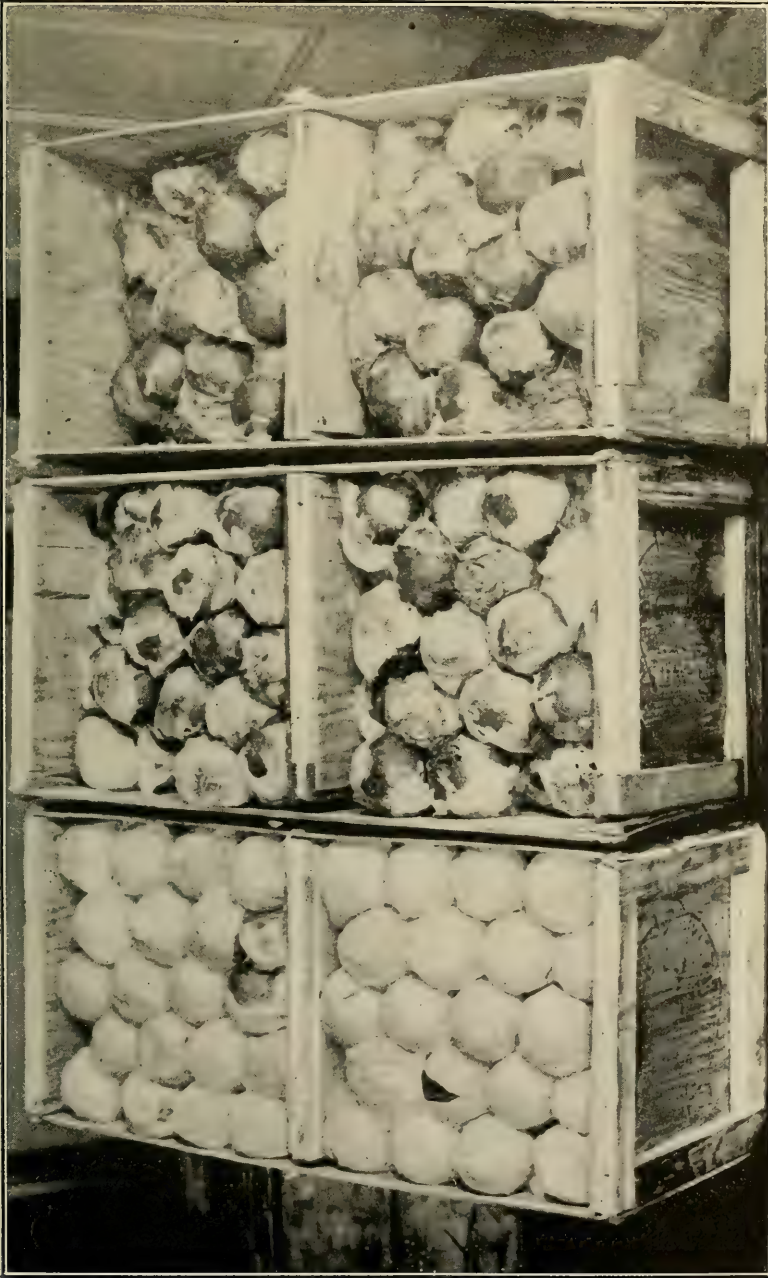
Showing the type of machinery used for grading citrus fruits. The interior of this building is shown in Plate XI, Figure 2.



FIG. 2.—GENERAL VIEW OF A CLEAN, WELL-ARRANGED BUILDING.

Showing new equipment for handling citrus fruits.

INTERIORS OF MODERN PACKING HOUSES IN FLORIDA.



FLORIDA ORANGE-SHIPPING EXPERIMENT, 1911.

Showing the condition of the fruit on arrival. From left to right: Careful pick and pack, commercial pick and careful pack, commercial pick and pack.

to the packing box. A sharp, ragged fragment of stem projecting from the orange will injure all the fruit with which it comes in contact in the picking bag, field box, brusher, washer, or packing bin. When it is considered that long stems are probably the most common imperfections found in the work of the Florida crews, the importance of giving particular attention to the picking becomes apparent. In most instances it is impossible to avoid leaving long stems, unless the so-called double cut is made. This means that the fruit is first severed from the tree with a stem half an inch long, which is trimmed off when the fruit is held in the hands of the picker. This enables the workman to cut closely and carefully without danger of clipper cutting, and at the same time it prevents him from throwing or "shooting" the fruit into the picking receptacle. Actual experience shows that it requires very little more time to make the double cut, and when the picker becomes accustomed to clipping in this way he can operate practically as fast as with the old method, where he has to use care to prevent clipper cutting. Of course, it takes longer to make a careful double cut than to pay no attention to the character of the work performed. Since the picker is frequently unable to see the stem when the orange is on the tree, he consumes much time in adjusting his clippers in the right position. In making the double cut he is not concerned with the placing of his clippers, simply reaching out and severing the orange with a stem long enough to avoid contact between the fruit and the clippers; then when he holds it in plain sight he can easily make a smooth, close cut.

EVOLUTION OF THE FLORIDA CITRUS INDUSTRY.

The results of the bureau investigations emphasize the importance of having the fruit arrive in market in good condition and of having it remain sound while in the hands of the wholesale and retail dealers. Shippers are frequently of the opinion that their interest in the condition of the fruit does not extend beyond the percentage of decay found on arrival. It is realized that buyers can claim allowance for such decay, and consequently shippers are usually anxious to prevent it. In their opinion any decay which results after the fruit is purchased is the buyer's loss. This impression is erroneous, for the decay which develops after the fruit is in market is just as direct a loss to the growers and shippers as that which appears during transit. Although the shipper does not have to make a cash allowance for decay occurring during the market-holding period, brands which fail to remain in good condition lose their reputation and ordinarily do not command as high prices as do those which are known for their good market-holding quality. The wholesale and retail merchants want oranges upon which they can depend to remain in sound condition. For such fruit they are willing to pay a premium, while fruit which develops a high percentage of decay before it can be sold has nothing but its cheapness to recommend it. A grower or shipper who consigns carelessly or poorly packed fruit with the expectation that it will remain sound until it gets into market deceives no one but himself. He may be able to dispose of a few cars at fair prices, but the buyers soon learn what to expect and prices fall accordingly. Fruit which develops a high percentage of decay while in the market is the poorest kind of an advertisement, not only for the brand under which it is packed, but also for the section of the State from which it is shipped.

In many cases growers and packers are anxious to do careful work, but they do not realize how many factors there are in the handling operations which may cause injury and therefore decay. They do not appreciate what careful handling means, and they underestimate its importance until the results are demonstrated to them. Injuries causing decay in citrus fruits while in transit and in market may occur from operations through which the fruit is put from the time it is taken from the tree until it is placed in the packing box. It is the prevention of these injuries in grove and

packing house that makes up careful handling, and both grower and packer are concerned in knowing how they are caused and how they may be eliminated.

At the time the department investigations were started the methods of handling Florida citrus fruits for shipment were extremely crude. Growers did their own picking, there was no uniformity of system, and the work was performed only indifferently well. These statements are not meant to reflect in any way upon the standing of the industry or to criticize the individuals who were concerned with the preparation of the fruit for market. Practically all of the imperfections were due to a lack of knowledge on the part of the growers and shippers and not to their desire to slight any of the important work. No one realized the effects of injury to the fruit, and few, if any, believed that injury was being inflicted. Growers and packers frequently greeted the department workers with the statement that practically no injury was being done to their fruit, whereas later examination often showed 15 or 20 per cent of their oranges to be injured in some way. The scattered nature of the industry was largely responsible for the crudeness with which the work was carried on. The old neighborhood competition in the production of high-grade, attractive fruit disappeared after the freeze, when the plantings were distributed so widely over central and southern Florida. Groves were more or less isolated, and a grower was frequently wholly ignorant of the type of work being done by other producers of citrus fruits.

When the department investigations were begun it seemed almost hopeless to expect that the results of the work could be made effective. The importance of getting in touch with every grower and shipper was realized from the start, yet without some central organization through which these individuals could be reached it seemed impossible to expect that improvements in the methods of handling could be inaugurated.

The changes which have taken place in Florida during the past five years are truly remarkable. The old type of packing house has almost entirely disappeared (Pl. X, figs. 1 and 2). Modern houses, equipped with the newest machinery for handling fruit properly, have been constructed in practically every citrus district in the State (Pls. XI and XII), so that at the present time the industry is particularly well provided with the mechanical appliances for doing good work. Plate XIV shows two views of clean, well-lighted, modern packing-house interiors as contrasted with the dark and crowded rooms of the old houses (Pl. XIII). The attitude of the growers and packers has changed more slowly, however. The department has conducted a large number of field demonstrations in order to educate pickers to the necessity of careful work, and although much has been accomplished in this line, as is shown by the tabulated figures given later on, much still remains to be done. The introduction of better handling methods is largely a business problem. It has to do with the reorganization of the forces of workmen and with the method of paying them rather than with the discovery of the cause of a particular form of decay.

In California the occurrence of injury in preparing the fruit for shipment was associated with the way in which the work was done. The pickers were paid by the box, and naturally each man was ambitious to pick as many boxes as possible during the day, irrespective of the character of his work. A premium was thus placed on rough handling. Several large companies, employing hundreds of men, demonstrated that by changing from the box-payment to the day-payment plan and by insisting upon careful work they could practically eliminate all picking injuries. A change in the plan of payment is not, in itself, sufficient to bring about better work, however; the workmen must be properly organized and supervised, and each individual picker must be held responsible for the character of his work. In California a change from the individual grower doing his own picking to the plan of association picking crews resulted in very great improvement in the character of the work. The same plan has more recently been carried out in Florida with very beneficial results.

INSPECTIONS OF PICKING CREWS AND FOREMEN.

Careful inspections of the work being done in different parts of the State have been made during practically every season since the work has been in progress. Table II and its accompanying diagram (fig. 3) show the average percentages of imperfections

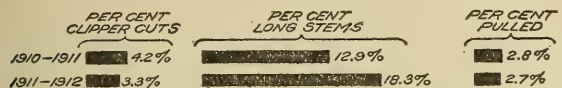


FIG. 3.—Diagram illustrating the percentage of imperfections in the work of a number of picking crews inspected during 1910-11 and 1911-12.

TABLE II.—Imperfections in the work of a number of picking crews inspected during 1910-11 and 1911-12.

Class of imperfections.	1910-11 ¹	1911-12 ²
	Per cent.	Per cent.
Clipper cuts.....	4.2	3.3
Long stems.....	12.9	18.3
Pulled.....	2.8	2.7

¹ Averages of 64 inspections of 51 crews.

² Averages of 35 inspections of 34 crews.

Since the crews which were inspected were located in different sections of the State, the percentages given in the table and graphically shown in figure 3 as the averages of all inspections represent very closely the type of work being done throughout Florida; they indicate the necessity for more careful attention to the details of picking and to the organization of the picking crews. This seems the most difficult reform to bring about, yet no permanent improvement in the carrying quality of Florida oranges will be reached until the field-handling operations are completely changed.

It is also necessary to devote more attention to inspecting the work of individual pickers. Table III and its accompanying diagram (fig. 4) show the results of the

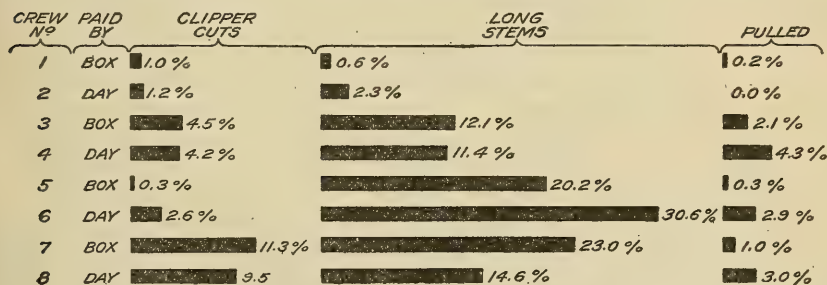


FIG. 4.—Diagram illustrating the percentage of imperfections in the work of different picking crews paid by the day and by the box, showing the variation in injury, 1910-11.

inspections of different picking crews in different parts of the State and are presented to show that good work is possible. Crews Nos. 1 and 2 were doing practically perfect work, but the work of crews Nos. 3, 4, 5, 6, 7, and 8 was far from perfect. The percentages of long stems for which these last crews were responsible ranged from 11.4 to 30.6 per cent.

TABLE III.—*Imperfections in the work of different picking crews paid by the day and by the box, showing variation in injury, 1910-11.*

Crew No.	Paid by—	Clipper cuts.	Long stems.	Pulled.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1.....	Box.....	1.0	0.6	0.2
2.....	Day.....	1.2	2.3	0
3.....	Box.....	4.5	12.1	2.1
4.....	Day.....	4.2	11.4	4.3
5.....	Box.....	.3	20.2	.3
6.....	Day.....	2.6	30.6	2.9
7.....	Box.....	11.3	23.0	1.0
8.....	Day.....	9.5	14.6	3.0

The percentages shown in Table IV and its accompanying diagram (fig. 5), which were obtained from two representative crews working in different parts of the State, give the average imperfections in the work of different individuals and show how wide a variation exists in the character of work performed.

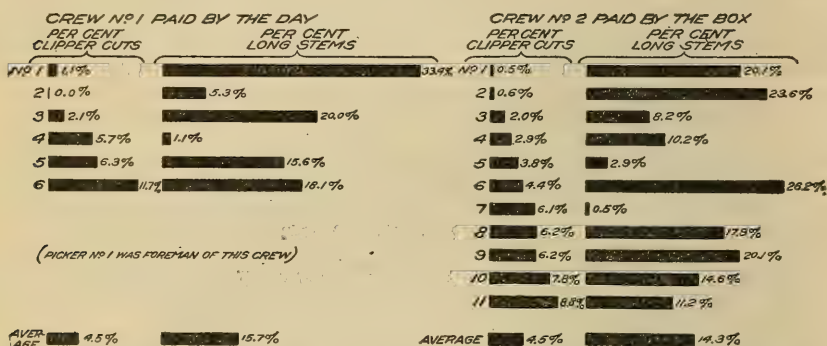


FIG. 5.—Diagram illustrating the percentage of imperfections in the work of two average picking crews, one paid by the day and one by the box, showing the variation between pickers, 1910-11.

TABLE IV.—*Imperfections in the work of two average picking crews, one paid by the day and one by the box, showing variation between pickers, 1910-11.*

Crew No. 1—paid by the day.			Crew No. 2—paid by the box.		
Picker No.	Clipper cuts.	Long stems.	Picker No.	Clipper cuts.	Long stems.
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
1 ¹	1.1	33.4	1.....	0.5	20.1
2.....	0	5.3	2.....	.6	23.6
3.....	2.1	20.0	3.....	2.0	8.2
4.....	5.7	1.1	4.....	2.9	10.2
5.....	6.3	15.6	5.....	3.8	2.9
6.....	11.7	18.1	6.....	4.4	26.2
			7.....	6.1	.5
			8.....	6.2	17.9
			9.....	6.2	20.1
			10.....	7.8	14.6
			11.....	8.8	11.2
Average.....	4.5	15.7	Average.....	4.5	14.3

¹ Picker No. 1 was foreman of this crew.

The figures are interesting and important because of the fact that the pickers in one crew were paid by the day while those in the other crew were paid by the box. It will be noted that there is practically no difference in the average percentages of imperfections in these two crews. In crew No. 1 the foreman was such in name only. He made no examination of the work of the men under his charge, and his own work was shown by inspection (he was picker No. 1) to be the poorest in the crew. He showed 1.1 per cent clipper cuts and 33.4 per cent long stems.

The pickers in crew No. 2, who were paid by the box, were not working with sufficient care to avoid all injury to the skin, yet the average of imperfections in the work of this crew was no greater than in the work done by crew No. 1, which was paid by the day. The simple change from the box-payment to the day-payment plan is insufficient, therefore, to bring about careful work. There must be an efficient

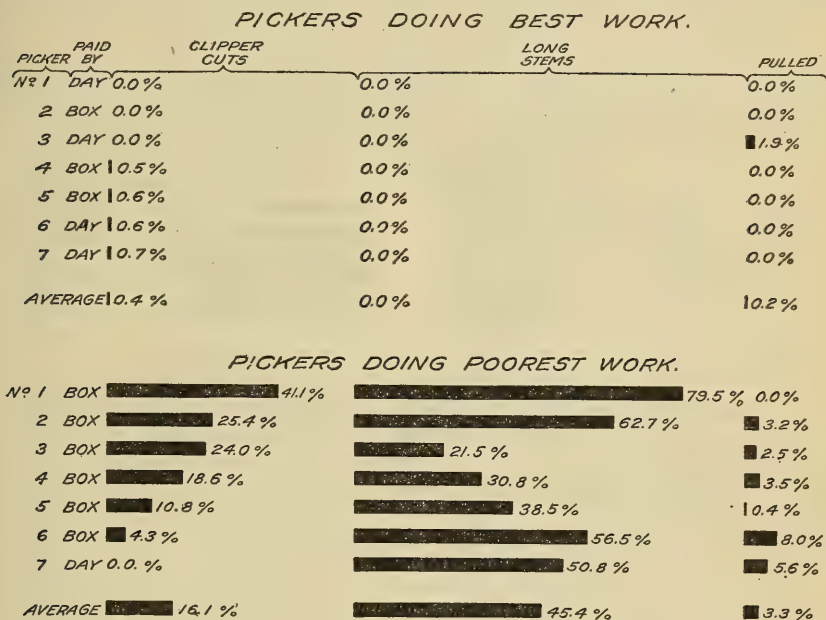


FIG. 6.—Diagram illustrating the percentage of imperfections in the work of seven pickers doing the best work and seven pickers doing the poorest work, 1910-11.

field foreman whose duty it is to supervise the different pickers and who must be capable of obtaining good work from them. He should watch carefully the output of every laborer under his charge, should follow them to see what each is doing, and should insist upon careful handling. It is practically impossible for him to carry out these arduous duties if, in addition, he must pick fruit. It will be found profitable to engage a foreman solely for the purpose of supervising the crew and to insist that he give his entire attention to this work; if necessary, he should be prohibited from picking any fruit.

The variation in the work done by different individuals is further emphasized by the percentages shown in Table V and the accompanying diagram (fig. 6). The average of the best seven pickers is practically perfect, while the average of the seven pickers doing the most careless work shows a very high percentage of imperfections of various kinds.

TABLE V.—*Imperfections in the work of seven pickers doing the best work and seven pickers doing the poorest work, 1910-11.*

Seven pickers doing best work.					Seven pickers doing poorest work.				
Picker No.	Paid by—	Clipper cuts.	Long stems.	Pulled.	Picker No.	Paid by—	Clipper cuts.	Long stems.	Pulled.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1.....	Day.....	0	0	0	1.....	Box.....	41.4	79.5	0
2.....	Box.....	0	0	0	2.....	do.....	25.4	62.7	3.2
3.....	Day.....	0	0	1.9	3.....	do.....	24.0	21.5	2.5
4.....	Box.....	.5	0	0	4.....	do.....	18.6	30.8	3.5
5.....	do.....	.6	0	0	5.....	do.....	10.8	38.5	.4
6.....	Day.....	.6	0	0	6.....	do.....	4.3	56.5	8.0
7.....	do.....	.7	0	0	7.....	Day.....	0	50.8	5.6
Average.....		.4	0	.2	Average.....		16.1	45.4	3.3

The importance of thoroughly inspecting the crews and of training the foremen to insist upon careful work is further emphasized by the percentages shown in Table VI and its accompanying diagram (fig. 7). These figures reveal very little difference in

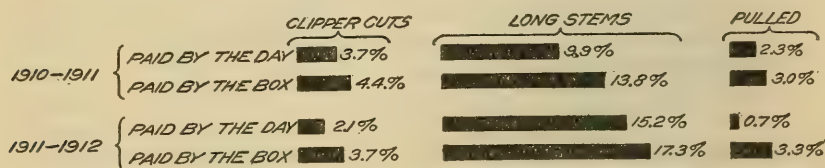


FIG. 7.—Diagram illustrating the percentage of imperfections in the work of crews paid by the day and by the box; average of all inspections, 1910-11 and 1911-12.

the averages of crews paid by the day and those paid by the box, proving that by means of careful supervision a conscientious foreman can get as good work from pickers under the box-payment plan as a more lax foreman can obtain under the day-payment plan. The efficient foreman is therefore the best solution of this problem.

TABLE VI.—*Imperfections in the work of crews paid by the day and by the box; average of all inspections, 1910-11 and 1911-12.*

Class of imperfections.	1910-11		1911-12	
	Crews paid by day. ¹	Crews paid by box. ²	Crews paid by day. ³	Crews paid by box. ⁴
Clipper cuts.....	<i>Per cent.</i> 3.7	<i>Per cent.</i> 4.4	<i>Per cent.</i> 2.1	<i>Per cent.</i> 3.7
Long stems.....	9.9	13.8	15.2	17.3
Pulled.....	2.3	3.0	.7	3.3

¹ Average of 18 inspections.

² Average of 46 inspections.

³ Average of 8 inspections.

⁴ Average of 27 inspections.

Table VII and figure 8 show the averages of imperfections in the work of five of the best and five of the poorest picking crews inspected during 1910-11 and 1911-12.

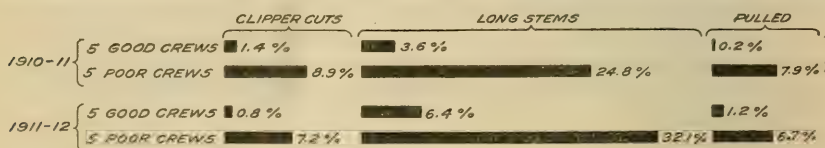


FIG. 8.—Diagram illustrating the average percentage of imperfections in the work of five picking crews doing good work as compared with five picking crews doing poor work, 1910-11 and 1911-12.

TABLE VII.—*Imperfections in the work of five picking crews doing good work as compared with five picking crews doing poor work, 1910-11 and 1911-12.*

Class of imperfections.	1910-11		1911-12	
	Five good crews.	Five poor crews.	Five good crews.	Five poor crews.
	Per cent.	Per cent.	Per cent.	Per cent.
Clipper cuts.....	1.4	8.9	0.8	7.2
Long stems.....	3.6	24.8	6.4	32.1
Pulled.....	.2	7.9	1.2	6.7

Along with the inspections of the work of the crews and the individual pickers, an attempt was made to demonstrate the practicability of training workmen to use more care. The workers of the Bureau of Plant Industry kept in close touch with the foreman of a representative picking crew, taking pains to indicate to him the scope and character of the inspections which it was desirable for him to make. In Table VIII and figure 9 are shown the results of work of this character. The first inspection

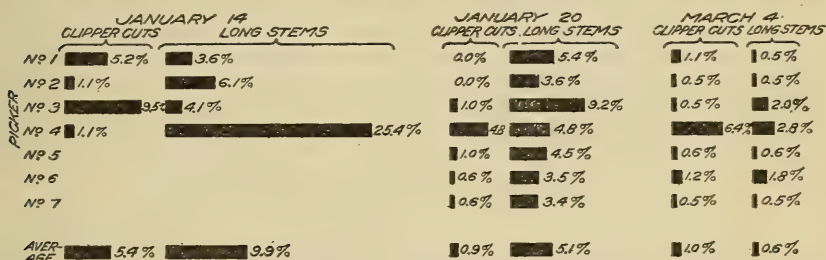


FIG. 9.—Diagram illustrating the percentage of imperfections found during three inspections of one picking crew ranging from three to seven persons, showing great improvement.

was made on January 14, when the crew consisted of four men, the average of imperfections at that time being 5.4 per cent clipper cuts and 9.9 per cent long stems. The importance of careful work was urged upon the foreman and crew, and when on January 20 a second inspection was made, a very material decrease was found in the percentages of imperfections. The crew had been increased to seven by that time, and the average of clipper cuts was 0.9 per cent and of long stems 5.1 per cent. After an additional demonstration of the effects of rough handling, no examination of the work of the crew was made until March 4, when the third and last inspection of the season was made. The average percentages of the seven pickers composing the crew on that date were 1 per cent clipper cuts and 0.6 per cent long stems. An examination of the work of the different individuals shows that one man (picker No. 4) was doing practically all of the clipper cutting, his average being 6.4 per cent; it will also be noted that his average of long stems (2.8 per cent) was greater than that of any of the other pickers. If it was impossible for this workman to improve the character of his picking he should have been discharged. Without him the average percentage of clipper cuts would have been reduced to 0.7 per cent and of long stems to 0.5 per cent.

TABLE VIII.—*Imperfections found during three inspections of one picking crew, showing great improvement.*

Picker No.	Jan. 14, 1911.		Jan. 20, 1911.		Mar. 4, 1911.	
	Clipper cuts.	Long stems.	Clipper cuts.	Long stems.	Clipper cuts.	Long stems.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1.....	5.2	3.6	0	5.4	1.1	0.5
2.....	1.1	6.1	0	3.6	.5	.5
3.....	9.5	4.1	1.0	9.2	.5	2.0
4.....	1.1	25.4	4.8	4.8	6.4	2.8
5.....			1.0	4.5	.6	.6
6.....			.6	3.5	1.2	1.8
7.....			.6	3.4	.5	.5
Average.....	5.4	9.9	.9	5.1	1.0	.6

While these figures plainly demonstrate the practicability of training a crew of pickers to do careful work, permanent improvement can not be accomplished without continuous attention to the details of inspection and constant urging of the workmen to better efforts. There are cases where picking operations were improved as long as the men thought that inspections would be made; as soon as these were discontinued, however, it frequently happened that the character of the work changed, and injuries again became common. Continual vigilance is therefore the prime requisite for carrying on picking operations in such a way that the number of injuries can be held at a minimum.

PROPER FIELD EQUIPMENT.

The efficiency of the foreman and of the picking force in general is frequently lowered by poor field equipment. In some instances associations of Florida growers have spent large sums in building and equipping modern packing houses, while their field outfits and methods have been neglected and consequently are so crude that the expensive packing-house equipment is of practically no value in so far as careful handling of the fruit is concerned.

A frequent source of injury is the clipper. Unless the shears are systematically inspected by the foreman they soon become dull and loose at the joint, and clipper cuts and long stems are almost sure to follow. It has not been uncommon to see a crew of pickers using clippers so dull and worn that it was impossible to make a close, clean cut. Clippers with rounded or blunted points should also be supplied in order to run no risk of puncturing the fruit.

The type of picking receptacle used is fundamentally important. Next to poor clippers, probably more injury is caused by poor picking sacks than by any other form of equipment. The old type of gunny sack, holding from three-fourths of a box to a full box of fruit, is still in use to some extent. Such a sack is so long that it is almost impossible to avoid pressing it against the ladder and branches. Moreover, it is made of such loosely woven material that the fruit may easily be punctured by thorns or twigs, and it is so heavy and unwieldy when filled with fruit that the picker can not always prevent injuries of this kind. The most objectionable feature, however, is the fact that the fruit must be emptied through the top of the sack into the field box, and even with the best of care the oranges must drop a foot or more when emptied in this way.

The best type of sack is one which opens at the bottom, so that it may be placed in the field box before being emptied and the fruit allowed to roll out gently without any appreciable drop. The mouth should be partly closed, so as to make it impossible for the picker to toss or drop the fruits into it. The material of which it is made

should be heavy enough to protect the fruit from thorns or twigs, and the capacity should not be more than half that of a large, standard field box. With a bag of this size and texture it is comparatively easy for the picker to protect the fruit from bruising against the ladder or branches. The wicker basket in use in some districts is supposed to prevent injuries from pressure, but it has several objectionable features. It is, first of all, awkward to handle. The wide mouth is an additional disadvantage, as it tempts the picker to drop the fruit; moreover, the large open baskets have no equals as collectors of dry twigs, leaves, and other trash. Some baskets open at the bottom, but from most of them the oranges must be emptied through the top, thus entailing a considerable drop.

The defects of the ordinary field box have already been discussed. Smaller boxes made of lighter material than those now used in most groves are to be recommended.

INFLUENCE OF CLEANING OPERATIONS UPON DECAY.

NECESSITY FOR WASHING.

On account of the wide distribution throughout Florida of the white fly and its attendant sooty mold, the washing of citrus fruits has become a necessity in most sections of the State. In some localities where the fly has not yet become prevalent washing is practiced in order to give the fruit a higher polish and to improve its appearance. The removal of dust and stains can be equally well accomplished by dry brushes, however, and the risk of infection is not so great. During the past few years there has been a great increase in the proportion of fruit washed or otherwise cleaned until now the practice is very general throughout the State. The investigations of the Bureau of Plant Industry included a study of the relationship of washing or other cleaning operations to the amount of decay developing after the fruit is packed, and the results indicate that the extent of the deterioration from decay varies with the character of the work done in the cleaning processes. As a general rule, any operation to which the fruit is subjected increases the chance for injury and consequent decay. Well-grown fruit, comparatively free from stain or rust, is sufficiently attractive without being cleaned. Demonstrations with both California and Florida citrus fruits have shown that receivers in eastern and northern markets can not distinguish between washed and unwashed packs if the fruit is at all clean when it comes from the grove. From the viewpoint of the effect of any particular operation upon the subsequent behavior of the fruit, the soundest policy is one which will reduce to the lowest possible minimum the processes to which the fruit is subjected in the course of its preparation for shipment. Washing is perhaps the severest treatment that can be given to citrus fruits, and wherever it is not absolutely necessary in order to render the fruit marketable it should be omitted. When oranges have been exposed to attacks of the white fly, washing or some other cleaning process is imperative because of the sooty mold, consequently a large proportion of the fruit must always be subjected to this treatment. The importance of having the work carried on in such a way that as little damage as possible will result becomes doubly urgent when it is considered that the washing processes offer ideal conditions for the spread of blue mold.

Wherever washing and subsequent drying are practiced, the combined operations are the most complicated processes through which the fruit is put in the packing house. They involve extra handling of the fruit and accordingly furnish additional opportunities for mechanical injury. The results of the bureau investigations clearly show that decay in the packed fruit is largely due to injuries received or aggravated during the operations of washing and drying, although it is difficult, if not impossible, to indicate any particular point at which most of the injury takes place. The results of the Florida experiments show that where injuries to the fruit were confined almost

wholly to those received in the commercial field-handling operations the decay was practically the same as in the case of lots where injuries were confined to those received in the washing and drying operations. From this the assumption may be drawn that the bad effects following washing are due not so much to actual injuries made in passing the fruit through the machine as to the inoculation of injured and bruised spots through the agency of dirty, infected water. There seems to be a definite relationship between the type of field handling and the occurrence of decay following washing. Injuries made in the grove, punctures from long stems, or other damage received as the oranges pass through the machinery are aggravated by the addition of moisture, especially when the water is not clean. On the other hand, the quality of work performed by the machinery is largely dependent upon the manner in which the fruit is handled in the grove, and this consideration emphasizes the necessity of careful and systematic methods, especially where washing must be employed. Fruit which is handled in groves and packing houses with sufficient care to insure its packing without injury usually shows much less decay after washing than the same or similar fruit which has been treated less carefully.

Fruit which is covered with sooty mold must be thoroughly soaked before it is in proper condition for washing. This introduces a prolific source of infection—the soaking tank. Unless the water in the soaking tank is kept sanitary by being frequently changed, it soon becomes heavily charged with blue-mold spores, and is then one of the most dangerous features of the washing operations. As yet, no disinfectant

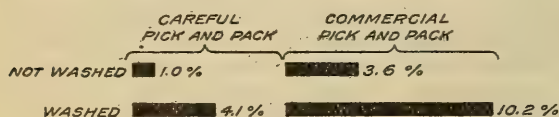


FIG. 10.—Diagram illustrating the percentage of blue-mold decay after holding oranges, washed and not washed, for two weeks in a packing house; summary of all experiments, 1910-11.

has been found which proves effective against blue mold. Extensive investigation of this phase of the subject has shown the spores to be so resistant that any solution used to destroy them must be of sufficient strength to injure

the surface of the fruit. The importance of maintaining the soaking tank in a sanitary condition is therefore fundamental. It should be emptied frequently, and sprays of fresh water should be directed against the fruit as it passes through the washing machine.

RESULTS OF WASHING EXPERIMENTS.

Tables IX, X, and XI, and figures 10, 11, and 12 show the results obtained during the season of 1910-11, when the washing experiments of the bureau were carried on in a comprehensive and systematic manner, giving the average percentages of decay found in carefully and commercially handled fruit, washed and not washed, respectively. The fruit was packed as if for shipment, but instead was held for two weeks in the packing houses and the percentages of decay determined by actual count. Table IX and its accompanying diagram (fig. 10) present a summary of all the washing experiments carried on during the season, including the work of 13 different types of machines, operated in 32 packing houses. The figures show the relative increase in decay due to the washing operations alone in the case of the carefully handled fruit and to the combination of causes in the case of the commercially handled fruit. The carefully handled oranges, not washed, showed 1 per cent of decay after two weeks; the washed, 4.1 per cent. In the commercially handled lots, the fruit not washed showed 3.6 per cent of decay and the washed fruit 10.2 per cent. The figures include the results of work done in many different ways, and while they summarize the general effects of washing, some analysis of the data is necessary in order to bring out the points of fundamental importance.

TABLE IX.—*Blue-mold decay after holding oranges, washed and not washed, two weeks in packing house; summary of all shipments, 1910-11.*¹

Treatment.	Careful pick and pack.	Commercial pick and pack.
Not washed.....	<i>Per cent.</i> 1.0	<i>Per cent.</i> 3.6
Washed.....	4.1	10.2

¹ Results of 37 experiments in 32 packing houses, in which 13 different types of washers were used.

Table X and its accompanying diagram (fig. 11) show the wide variation in the amount of decay found in five houses selected for careful work, as compared with five houses chosen for rather careless work. While the average percentages of decay in the washed fruit of the five better houses were only slightly higher than the percentages of decay in the fruit not washed, it will be noted that the cleaning operations in the five careless houses increased the amount of decay to a material extent, even in the carefully picked and packed fruit. The significant point to be noted in these results is that the washing operations were conducted in the careful houses in such a way that little or no harm ensued, while in the more careless houses they were followed by serious injury. It is impossible to state definitely whether this result was due to the use of different types of machines or to the more careful operation of the machinery in the five best packing houses. It is probable, however, that both factors were in some degree responsible. Observation has shown that careless manipulation of the best machinery is frequently followed by as serious deterioration of the fruit as is the careful handling of less desirable types of machines.

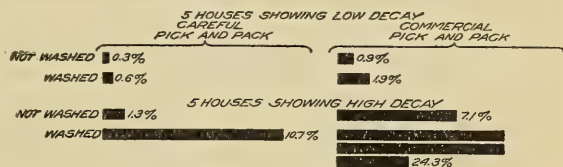


FIG. 11.—Diagram illustrating the percentage of blue-mold decay appearing after holding oranges, washed and not washed, for two weeks in a packing house, showing high compared with low decay in carefully handled and commercially handled fruit.

TABLE X.—*Blue-mold decay after holding oranges, washed and not washed, two weeks in a packing house, showing high and low decay in fruit carefully handled and commercially handled, 1910-11.*

Packing houses and treatment.	Careful pick and pack.	Commercial pick and pack.	Packing houses and treatment.	Careful pick and pack.	Commercial pick and pack.
5 houses showing low decay:	<i>Per cent.</i>	<i>Per cent.</i>	5 houses showing high decay:	<i>Per cent.</i>	<i>Per cent.</i>
Not washed.....	0.3	0.9	Not washed.....	1.3	7.1
Washed.....	.6	1.9	Washed.....	10.7	24.3

In order to bring out the relationship between field handling and packing-house management, Table XI and its accompanying diagram (fig. 12) are presented. These give the results of experiments made at the same time in two houses in the same locality, the character of fruit handled in both houses being practically identical. Observation showed that the work of house No. 1 was careless, while in house No. 2 systematic management and careful methods prevailed. That the character of the fruit was the same is shown by the fact that the lots carefully picked and not washed showed a minimum percentage of decay in both cases. The fruit was held two weeks after

packing, and decay was determined by actual count. In house No. 1 the carefully handled fruit, not washed, was held for two weeks with only 1.1 per cent of decay, while the washed lot of the same fruit developed 14.1 per cent. The carefully handled oranges, not washed and washed, showed 0.8 per cent and 1 per cent of decay, respectively, in house No. 2. The commercially handled fruit, not washed, in house No. 1 developed 4.7 per cent of decay after two weeks, while in house No. 2 this class of fruit

showed only 1.2 per cent of decay. There was 39.5 per cent of decay in the washed lots of commercially handled fruit from house No. 1, but in house No. 2 only 1.3 per cent of the fruit handled in the same way showed decay at the end of two weeks.

The significance of the effects of rough field handling and subsequent poor manipulation of the machinery is

amply shown, and the practicability of carrying on washing operations with care sufficient to reduce decay to a minimum is likewise demonstrated.

TABLE XI.—Blue-mold decay in oranges, washed and not washed, from two houses in the same locality after holding the fruit for two weeks in the packing houses, 1910-11.

Packing houses and treatment.	Careful pick and pack.	Commercial pick and pack.	Packing houses and treatment.	Careful pick and pack.	Commercial pick and pack.
House No. 1:	Per cent.	Per cent.	House No. 2:	Per cent.	Per cent.
Not washed.....	1.1	4.7	Not washed.....	0.8	1.2
Washed.....	14.1	39.5	Washed.....	1.0	1.3

In the bureau investigations 12 different types of washing machines and one sawdust cleaner were used. A few of the machines were of such evident impracticability that they were rapidly going out of use, and of those which gave satisfactory results it is manifestly impossible to name any one which is best suited for all purposes. The quantity of fruit to be handled and the nature of the work to be performed are important factors which must be considered in determining the value of any machine. When purchasing this part of the equipment, it is important to choose the type of machine which will do the best work from the standpoint of careful handling and will eliminate, as far as is possible, the detrimental results of washing.

Some of the features which should be avoided in washing machines are as follows:

(1) Completely inclosed brushes. The fruit should be in plain sight at all times.
 (2) Pressure on the fruit other than that afforded by the weight of the fruit itself.
 (3) Opportunity for the fruits to tumble over or rub against one another to any great extent.

(4) Any arrangement of brushes, mats, etc., which allows twigs, thorns, nails, etc., to become lodged in the runway through which the fruit must pass.

Any one of these features may be the means of much injury, especially in houses where careful attention to the operation of the machinery is not given at all times, or where the field-handling operations have been more or less careless.

IMPORTANCE OF DRYING.

Fruit should never be packed while moist or wet. Moisture is one of the prime requisites for the development of decay, and, as the temperature of the fruit during the Florida packing season is usually high enough to facilitate the germination of the

mold spores, the importance of having the fruit perfectly dry can not be too strongly emphasized. Weather conditions in Florida are practically never such that fruit may be allowed to stand wet in the boxes for several days, although this practice prevails to some extent in California. The wet conditions within the mass of fruit renders ideal the conditions for the development of any mold, especially where the packing-house premises are not strictly sanitary. Injured fruits handled in this way frequently develop decay which has not advanced far enough to be detected when the fruit passes over the grading belts and which might have been prevented by prompt drying. Later drying or even icing in transit can not entirely arrest the growth of the mold.

In some districts the sun rack (Pl. VII, fig. 2) is depended upon for drying the fruit, and with favorable weather conditions this method is as effective as the use of many of the so-called artificial-drying machines. The chief objection to this rack is that frequently sufficient space for its proper construction is not available, and it is therefore not made large enough to accommodate all of the fruit or to insure perfect drying. Moreover, the handling of the fruit on this rack is often very rough and conducive to severe injury, unprotected brooms or wooden implements being generally used to dislodge the fruit or to spread it over the rack as it comes from the washing machine. Another point of injury is where the fruit is allowed to run off the bottom of the rack into the field boxes, from which it is again emptied into a hopper leading to the grading machine. These various operations and the more or less rough type of handling greatly multiply the chances for injury and increase the liability of blue-mold infection.

The drying of fruit in Florida is difficult at best, and the artificial drier seems to be an ultimate necessity, at least from the standpoint of thorough work and careful handling. Frequently weather conditions are such that complete drying is practically impossible unless some artificial method is devised to evaporate the water from the surface of the fruit. A properly constructed drying machine can be adjusted so as to carry the fruit continuously from the washing machine to the grading belts, without drops, gravity runs, elevators, or even the use of the human hand. A machine which can thus be adjusted to carry on the work with proper care is more reliable than are workmen of the type usually employed in a packing house.

The artificial drying of fruits is still in the experimental stage in Florida, and a machine which will prove wholly satisfactory under all conditions has not yet been devised. All the types of mechanical driers have yielded good results under favorable weather conditions, and all have given more or less trouble on cloudy days or at any time when the humidity was very high.

In the most effective driers now in use, an air blast is circulated around the fruit in such a way that the moisture is more or less completely removed. The introduction of artificial heat or some other means of drying the circulating air will greatly improve the character of the work and will materially lessen the distance over which the fruit must travel. Other things being equal, the more promptly the drying can be accomplished the less chance there will be for the development of blue mold.

PACKING AND SHIPPING EXPERIMENTS.

EXPERIMENTAL CONSIGNMENTS DURING TWO SEASONS.

During the seasons of 1910-11 and 1911-12 comprehensive series of shipping experiments were made in order to demonstrate the application of the results of the packing-house tests made during previous years. More than 90 experimental shipments of oranges were made from Florida in 1910-11, and 65 shipments were sent out in the course of the work during 1911-12. These consignments were composed of fruit from practically every orange-growing district in the State, including the Manatee River district, the Pinellas Peninsula, and the Hillsboro County sections on the west coast; the groves extending from Fort Myers to De Land in the interior; and

the section along the east coast from Daytona and New Smyrna to Miami. They represented a great variety of conditions and formed a fair average of the character of the fruit in the State, as well as of the manner in which it was prepared for market under commercial conditions. Some of the best as well as some of the poorest houses were represented in these tests, and a number of houses which may be classed as average were also included.

Each shipping series consisted of six boxes of oranges; two of these were carefully picked, graded, and packed by the bureau workers; two were picked by regular pickers but were carefully graded and packed; and the last two were taken from the ordinary commercial run of the houses from which the experimental shipments were made. The shipments were divided into two parts. In one the grading, packing, and shipping were made on the same day on which the fruit was picked, or as soon afterwards as possible, and in the other the same fruit was held for three or four days in the packing house before packing and shipping. The former were designated as "immediate" and the latter as "delayed" shipments. All lots were sent out with the regular carloads of fruit from the various packing houses, and the experimental boxes were expressed to Washington from the northern markets to which the cars were consigned. Each box was inspected on the day of arrival in Washington and the percentage of decay accurately determined. The fruit was held for three weeks under ordinary open-market conditions, and inspections were made at the end of the first, second, and third weeks. The results obtained give a fair representation of the average decay occurring in a commercial pack and show the percentage of loss which can be avoided by more careful handling.

Plate XV illustrates the condition in which the three lots shipped from one packing house using very little care arrived on the Washington market. The carefully picked, graded, and packed fruit (on the left in the illustration) showed 4 per cent of decay on arrival; the commercially picked but carefully graded and packed fruit (in the center) showed 35.6 per cent of decay, and the commercially handled fruit (on the right) had 65.9 per cent of decay. After intervals of one, two, and three weeks the three lots, respectively, showed decay as follows: After one week, 4 per cent, 46 per cent, and 71.6 per cent; after two weeks, 11.5 per cent, 54 per cent, and 72.2 per cent; after three weeks, 11.5 per cent, 57.1 per cent, and 72.2 per cent.

Table XII and figure 13 show the average percentages of decay found in the shipments during 1910-11 and 1911-12.

TABLE XII.—*Blue-mold decay in oranges carefully handled and commercially handled, on arrival in Washington and after holding for three weeks; average of all inspections, 1910-11 and 1911-12.*¹

Time of examination.	Careful pick and pack.		Commercial pick and careful pack.		Commercial pick and pack.	
	1910-11	1911-12	1910-11	1911-12	1910-11	1911-12
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
On arrival.....	0.6	0.6	2.5	1.4	7.0	4.0
After 1 week.....	1.1	.9	4.3	2.2	10.8	6.8
After 2 weeks.....	1.6	1.4	5.5	3.5	13.1	10.4
After 3 weeks.....	1.9	2.2	6.1	5.5	14.2	14.2

¹ From 79 comparable shipments made in 1910-11 and 65 comparable shipments made in 1911-12.

Table XIII and its accompanying diagram (fig. 14) summarize the results of the two seasons' work and show the average of all experiments carried on during the two years. In the illustration the results are marked as curves, using the percentages of decay for the vertical lines and the times of arrival and of holding for the horizontal lines. In this way the progress of the deterioration can readily be traced, and the influence of the different systems of handling upon the occurrence of decay is strikingly shown.

The carefully handled fruit arrived in Washington during both seasons with less than 1 per cent of decay, or an average for the two years of 0.6 per cent. The commercially picked but carefully packed fruit showed much more decay on arrival, while a still higher percentage of decay had developed in the fruit picked and packed under ordinary commercial conditions. The average percentage of decay which was developed in the carefully picked and packed fruit during a holding period of three weeks was about the same as that shown on arrival by the commercially picked but carefully packed lots. The fruit handled under commercial conditions throughout

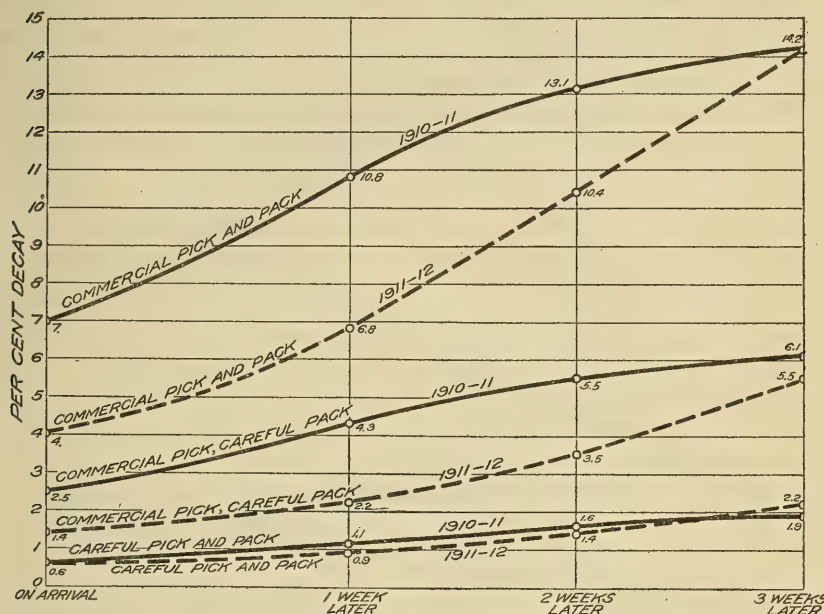


FIG. 13.—Diagram illustrating the percentage of blue-mold decay in carefully handled and commercially handled oranges on arrival in Washington and after holding for three weeks; average of all inspections, 1910-11 and 1911-12.

had developed more than twice as much decay by the first inspection as occurred in the carefully picked and packed fruit at the end of three weeks. The latter boxes, with 2.1 per cent of decay, were still in good marketable condition after holding for three weeks under ordinary market conditions, but the commercially handled fruit had developed 5.5 per cent of decay on arrival, which was increased to 14.2 per cent at the end of three weeks.

TABLE XIII.—Blue-mold decay in oranges carefully handled and commercially handled, on arrival in Washington and after holding for three weeks; summary of the results of the two seasons' work, 1910-11 and 1911-12.¹

Time of examination.	Careful pick and pack.	Commercial pick and careful pack.	Commercial pick and pack.
	Per cent.	Per cent.	Per cent.
On arrival.....	0.6	2.0	5.5
After 1 week.....	1.0	3.3	8.8
After 2 weeks.....	1.5	4.5	11.8
After 3 weeks.....	2.1	5.8	14.2

¹ From 79 comparable shipments made in 1910-11 and 65 comparable shipments made in 1911-12.

These results strongly emphasize the very definite relationship which exists between the type of handling given the fruit in preparing it for shipment and its behavior during transit, and they show that the condition of the fruit after arrival in market depends largely upon the character of the work done in the grove and the packing house. They also show that the Florida orange, when properly handled, has excellent shipping qualities and that practically all loss from blue-mold decay, such as has occurred in the past, can be eliminated. This is the fundamental factor upon which will eventually depend the successful marketing of the crop as well as the extension of the territory over which sound fruit can be distributed. The importance of having the fruit remain in good condition after arrival in market is most urgent. Carefully handled fruit which has good keeping quality will always command a premium over fruit which has a bad reputation. The former will enable buyers to break up carloads and to ship sound fruit to smaller markets over an area two or three times as large, while

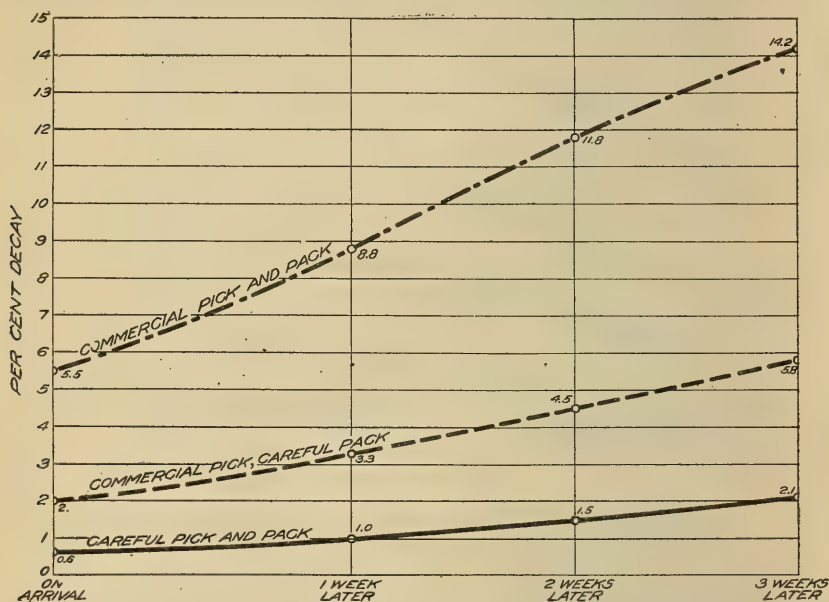


FIG. 14.—Diagram illustrating the percentage of blue-mold decay in carefully handled and commercially handled oranges on arrival in Washington and after holding for three weeks; summary of the results of the two seasons' work, 1910-11 and 1911-12.

fruit of a less desirable quality must be consumed quickly in order to avoid further serious loss. Moreover, aside from the actual saving of fruit, the reputation of a brand which holds well on the market can not be adequately estimated in dollars and cents.

EFFECT OF DELAYED SHIPMENT.

Experiments with delayed shipments were made in order to determine the effect of "curing" fruit before packing. One of the strongest traditions which existed among packing-house men in the past was that curing was necessary in order that the fruit might be in proper condition for packing. The slight wilting and consequent softening of the oranges was supposed to enable the packer to place them more firmly in the box. The results of the shipping experiments carried on during the two seasons did not show that there was any advantage to be gained from curing. Contrary to the general belief that cured fruit is less easily injured in packing, the average decay in the delayed lots was considerably higher than in the immediate shipments. Table XIV and figures 15, 16, and 17 give the average percentage of decay found in the

immediate and delayed shipments during the seasons of 1910-11 and 1911-12. Sufficient data have been accumulated to indicate that carefully handled fruit may be cured without serious loss, but that wherever the fruit has been appreciably damaged in the course of its preparation for shipment, decay is materially greater in the delayed lots. The carefully handled immediate and delayed shipments during 1910-11 and 1911-12 arrived with 0.5 per cent and 0.7 per cent of decay, respectively, the difference being so slight that it may be neglected entirely. The commercially handled immediate shipments showed 4.6 per cent of decay and the delayed ones 6.6 per

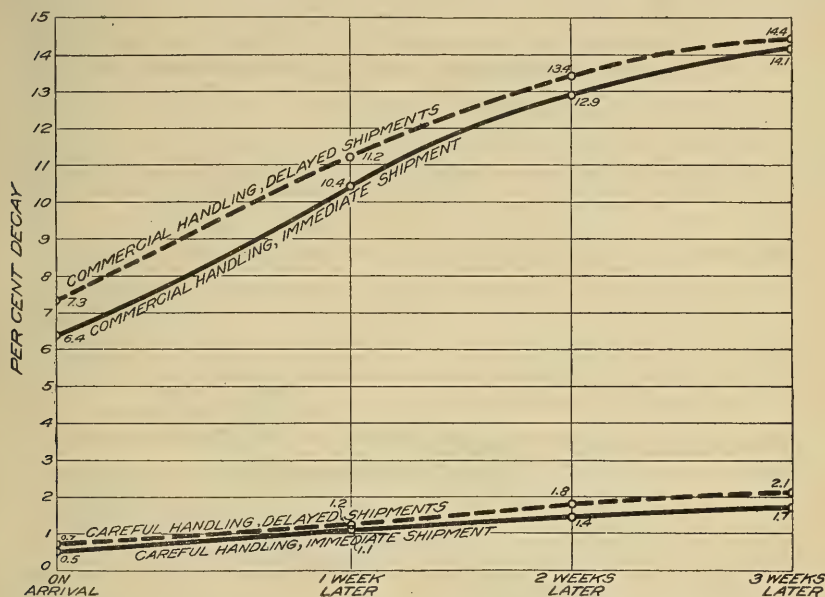


FIG. 15.—Diagram illustrating the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in carefully handled and commercially handled lots and in immediate and delayed shipments, 1910-11,

cent on arrival. After holding these lots of fruit for three weeks the decay in the carefully handled fruit had increased to 2 per cent, while the commercially handled shipments showed 13.8 per cent of decay for the immediate and 14.8 per cent for the delayed ones. Once again the effect of careful handling upon the behavior of the fruit after arrival in market is strikingly shown.

TABLE XIV.—Blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in carefully handled and commercially handled and in immediate and delayed shipments, 1910-11 and 1911-12.¹

Time of examination.	Careful pick and pack.			Commercial pick and pack.		
	1910-11	1911-12	Average 2 seasons.	1910-11	1911-12	Average 2 seasons.
On arrival:						
Immediate.....	Per cent. 0.5	Per cent. 0.5	Per cent. 0.5	Per cent. 6.4	Per cent. 2.9	Per cent. 4.6
Delayed.....	.7	.7	.7	7.3	5.8	6.6
After 1 week:						
Immediate.....	1.1	.9	1.0	10.4	5.7	8.1
Delayed.....	1.2	1.0	1.1	11.2	8.7	9.9
After 2 weeks:						
Immediate.....	1.4	1.4	1.4	12.9	9.7	11.3
Delayed.....	1.8	1.5	1.7	13.4	11.7	12.5
After 3 weeks:						
Immediate.....	1.7	2.3	2.0	14.1	13.5	13.8
Delayed.....	2.1	2.0	2.1	14.4	15.1	14.8

¹ From 39 comparable shipments made in 1910-11 and 28 comparable shipments made in 1911-12.

The prevailing opinion that fruit packed soon after picking or before it has had time to cure will arrive in slack condition has not been borne out by the bureau investigations. When the fresh fruit is firmly and properly placed in the box, it is no more liable to make a slack pack than is the cured fruit. It is probably true that the latter can be more easily packed, for less effort is required to press it into the box. The work of many rapid packers who make no effort to place the oranges firmly and who rely upon the press to squeeze the fruit into place, is conducive to poor carrying quality as well as to slackness. Each layer must be properly placed. Where the press is depended upon to shove the fruit down into the box the force exerted reaches through only two or three layers and often squeezes the oranges in these to the extent of breaking the skin or inflicting serious bruises. After the boxes are loaded on the cars, jolting during transit loosens the improperly packed layers, and the fruit arrives on the market in a slack condition. When every orange is firmly placed, however, there is little chance that such slackening will result.

Moreover, fruit held loose in the packing house during warm, humid weather is afforded an additional opportunity for blue-mold infection. Although some packers

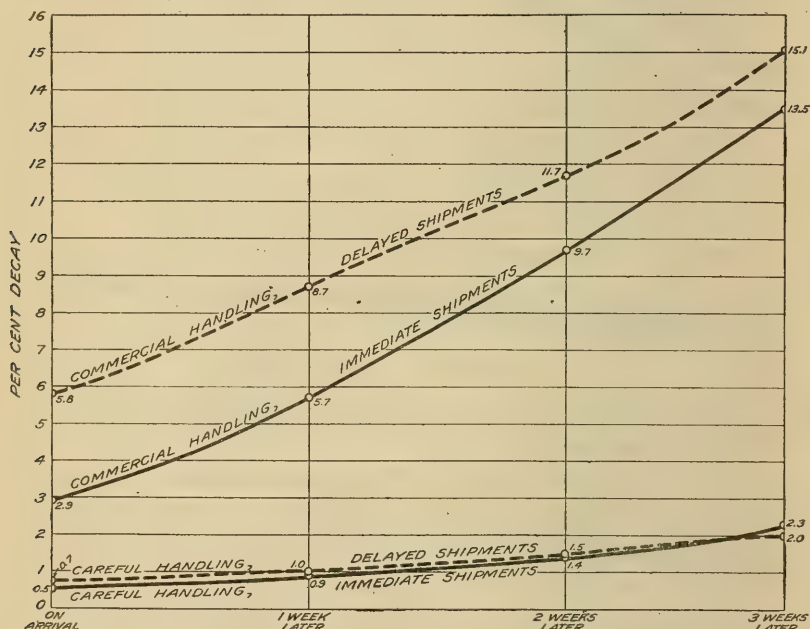


FIG. 16.—Diagram illustrating the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in carefully handled and commercially handled lots and in immediate and delayed shipments, 1911-12.

consider this delay necessary in order to eliminate the injured oranges which have begun to decay, experience and observation show that while graders are occasionally able to discern and throw out such fruits, it is practically impossible to discover all infected specimens. The development of blue mold during the curing period accounts for the advanced stages of the decay usually found in delayed shipments on arrival in market.

The average length of time during which the experimental shipments were in transit from Florida to Washington was 10 days; as a rule, from 8 to 10 days are required for Florida oranges to arrive at their destination. Several days may then elapse before the fruit is sold, and a still longer period usually intervenes before it is placed in the hands of the consumer. The 3-weeks' period used in the Washington market-holding tests represents approximately the length of time required to finally dispose of the

fruit. When the fruit is held for 3 or 4 days in the packing house the period elapsing between picking and final consumption is unnecessarily and even dangerously lengthened. From this standpoint alone curing is unwise, as the delay increases the chance for the infection of bruises or injured spots and facilitates the development of decay before shipment and in transit.

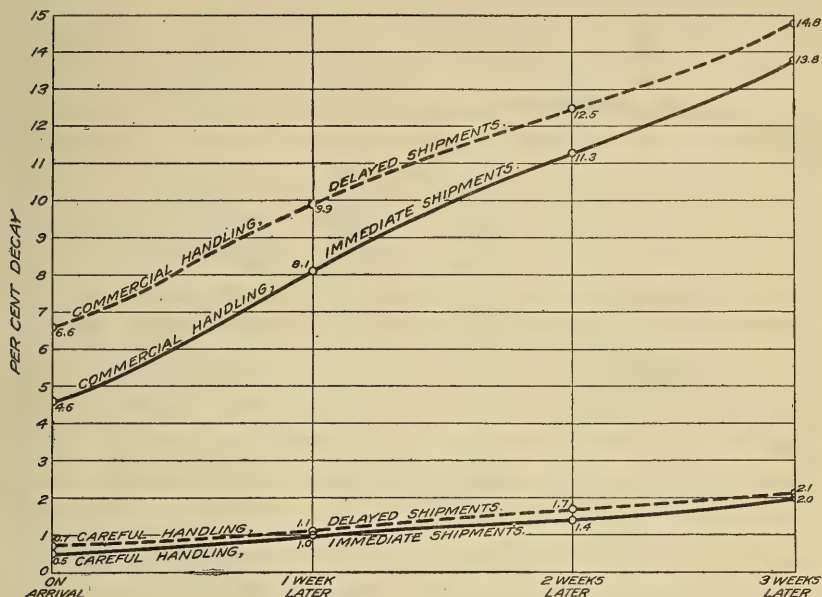


FIG. 17.—Diagram illustrating the percentage of blue-mold decay of oranges, on arrival in Washington and after holding for three weeks, in carefully handled and commercially handled lots and in immediate and delayed shipments; average of the two seasons, 1910-11 and 1911-12.

A comparison of commercially handled immediate and delayed shipments from two packing houses, in one of which the work was being done very carefully, while in the other the handling was of a rather rough character, emphasizes the relationship which exists between delay and the occurrence of decay while in transit. Table XV and its accompanying diagram (fig. 18) give the results of commercial shipments from these two packing houses during the season of 1910-11. The houses were located in the same district and the fruit was similar in character.

TABLE XV.—Blue-mold decay of oranges on arrival in Washington and after holding for three weeks, the immediate and delayed shipments from two houses, 1910-11.

Time of examination.	House No. 1.		House No. 2.	
	Immedi-ate.	Delayed.	Immedi-ate.	Delayed.
On arrival.....	Per cent. 0	Per cent. 0	Per cent. 26.1	Per cent. 67.3
After 1 week.....	1.2	.6	40.4	71.3
After 2 weeks.....	3.1	1.4	42.6	71.9
After 3 weeks.....	4.0	1.4	42.8	71.9

The fruit from house No. 1, which was carrying on the work in a careful manner, arrived in Washington with no decay in either immediate or delayed lots, and after holding for three weeks the immediate shipments developed 4 per cent of decay, while the delayed ones had less than 2 per cent. In house No. 2, where the work was being carelessly done, the difference between the percentages of decay was very

great. It will be noticed that even in the immediate shipments the proportion of decayed oranges amounted to 26.1 per cent on arrival and at the end of three weeks constituted 42.8 per cent of the total. In the delayed shipments, 67.3 per cent of decay had developed on arrival, and this was increased to 71.9 per cent after three weeks. This is an extreme case, of course, and it is only fair to state that few houses in Florida were doing as poor work as this during 1910-11. The figures are presented to emphasize the contrast between commercial work performed under different conditions.

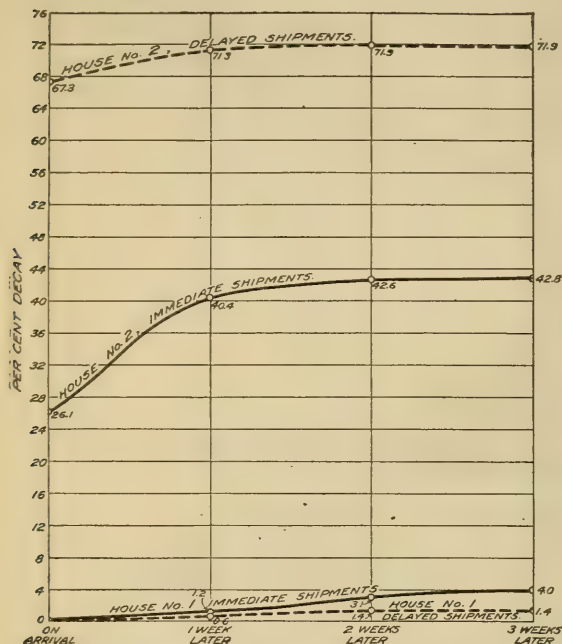


FIG. 18.—Diagram illustrating the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in immediate and delayed shipments from two houses, 1910-11.

showed 36.9 per cent at the same time. After holding the carefully handled fruit in Washington for three weeks, the immediate shipment was still in very good marketable condition with only 2 per cent of decay, whereas the percentage in the delayed lot had increased to 6.3. The latter fruit was still marketable, although subject to discount. Both lots of commercially handled fruit, however, developed decay far in excess of any market allowance, the immediate lot showing 25.6 per cent and the delayed 44 per cent.

TABLE XVI.—Blue-mold decay of oranges in immediate and delayed shipments from one house, on arrival in Washington and after holding for three weeks during a period of high blue-mold decay, December, 1911.

Time of examination.	Carefully handled fruit.		Commercially handled fruit.	
	Immedi-ate.	Delayed.	Immedi-ate.	Delayed.
	Per cent.	Per cent.	Per cent.	Per cent.
On arrival.....	1.0	3.6	5.1	36.9
After 1 week.....	1.0	4.6	16.5	38.0
After 2 weeks.....	1.2	5.3	23.3	39.4
After 3 weeks.....	2.0	6.3	25.6	44.0

Unless unfavorable weather conditions prevail, a delay of several days is not serious under a system of careful handling which insures the packing of the fruit in sound condition, but it is far better to avoid delay as much as possible, even if the attendant conditions are most favorable.

COMPARISON OF THE WORK OF DIFFERENT PACKING HOUSES.

Typical rough and careful handling.—The figures presented in Tables XVII to XX and the accompanying diagrams include the averages of both commercial and experimental shipments from a number of houses representing all classes of work. Extremes of rough handling and consequent very high decay during transit, as well as extremes of careful handling accompanied by excellent shipping quality, were found in different parts of the State.

Table XVII and its accompanying diagram (fig. 20) give the average percentages of decay occurring during 1910-11 and 1911-12 in the commercial shipments from 12 houses using care and from a like number of houses in which the work was roughly done. During both seasons the percentage of decay in the commercial fruit shipped by the houses using care was almost as low as the average for any of the carefully handled lots, picked, graded, and packed by bureau workers. The practicability of conducting commercial operations with sufficient care to eliminate decay is thus plainly demonstrated. The results of the two series of shipments present a striking and consistent contrast throughout both seasons. The averages of the carelessly handled commercial lots were somewhat lower during 1911-12 than they were in 1910-11, but the proportion of decayed fruit on arrival (10.9 per cent) is still too high for good commercial results.

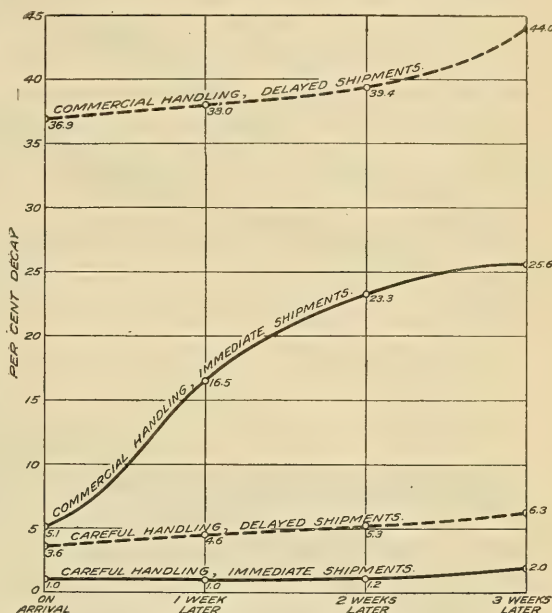


FIG. 19.—Diagram illustrating the percentage of blue-mold decay of oranges in immediate and delayed shipments from one house, on arrival in Washington and after holding for three weeks during a period of high decay, December, 1911.

TABLE XVII.—Blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in shipments showing high and low blue-mold decay in careful and in commercial pack, 1910-11 and 1911-12.

Year.	Inspection.	12 shipments showing low decay.		12 shipments showing high decay.	
		Careful.	Commercial.	Careful.	Commercial.
		Per cent.	Per cent.	Per cent.	Per cent.
1910-11...	On arrival	0.1	0.4	0.4	14.6
	After 1 week	.2	.8	.8	22.2
	After 2 weeks	.2	1.3	1.5	27.8
	After 3 weeks	.3	1.6	2.1	30.8
1911-12...	On arrival	.1	.6	1.1	10.9
	After 1 week	.3	1.7	1.3	16.1
	After 2 weeks	.6	3.0	1.7	20.5
	After 3 weeks	1.2	4.4	2.7	25.9

Table XVIII and figure 21 give the average percentages of decay of oranges from two packing houses in the same locality working on practically the same kind of fruit. The type of work in house No. 1 was good, but that in house No. 2 was rather poor. These shipments were made at the same time, and the results of carefully handled lots prepared by the bureau workers from the same houses are given for comparison.

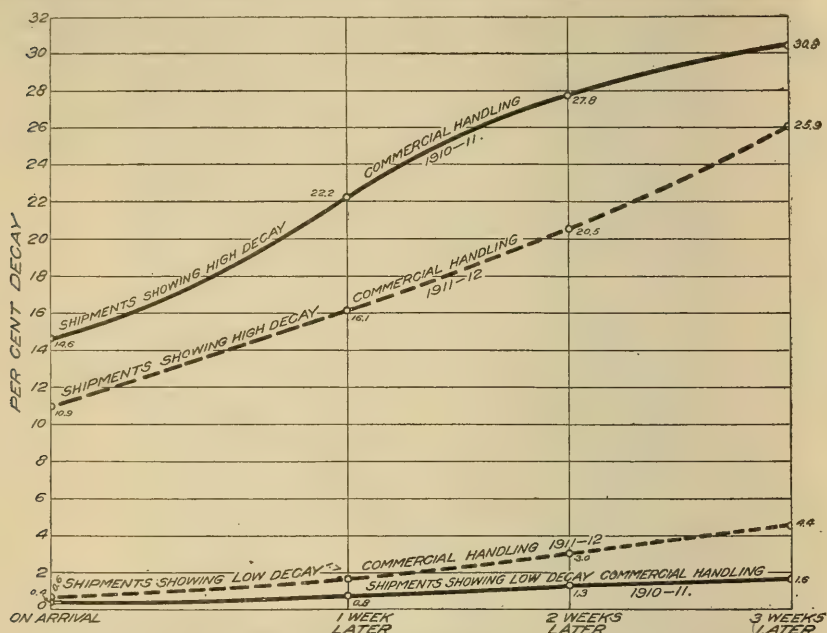


FIG. 20.—Diagram illustrating the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in shipments showing high compared with low decay in commercial pack, 1910-11 and 1911-12.

TABLE XVIII.—Blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in carefully handled and commercially handled lots shipped from two houses in the same locality, 1910-11.

Time of examination.	House No. 1.		House No. 2.	
	Careful.	Com-mercial.	Careful.	Com-mercial.
On arrival.....	Per cent. 0.4	Per cent. 2.4	Per cent. 0.3	Per cent. 21.3
After 1 week.....	1.5	4.5	.3	28.9
After 2 weeks.....	1.8	5.7	.3	48.2
After 3 weeks.....	2.5	5.7	.7	59.5

It will be noticed that the commercial shipment from house No. 1 gave practically as favorable returns as the specially prepared shipments of the bureau workers, the difference being only 2 per cent, both series from this house having less than the commercial allowance of 3 per cent decay on arrival. The commercial shipments from house No. 2, where observation showed the handling to be rather careless, had developed 21.3 per cent of decay on arrival at Washington, while the fruit handled by the bureau workers at the same time and shipped under identical conditions showed 0.3 per cent of decay. After three weeks the commercial shipments from house No. 1 averaged 5.7 per cent of decay, and those from house No. 2 showed 59.5 per cent, as against 2.5 per cent and 0.7 per cent, respectively, for the carefully handled fruit.

Relation of character of picking to decay.—A study of field handling in connection with the occurrence of decay in commercial shipments was made in two packing houses in Florida during 1911-12. It would be hard to find a more striking illustration of the effects of careless handling than that presented in Table XIX and in the diagram (fig. 22). It should be borne in mind that all of these results were obtained from lots of commercially handled fruit, no attempt being made by the bureau workers to influence the type of handling. They merely inspected the field work and made sure that the boxes selected for experimental shipment were representative.

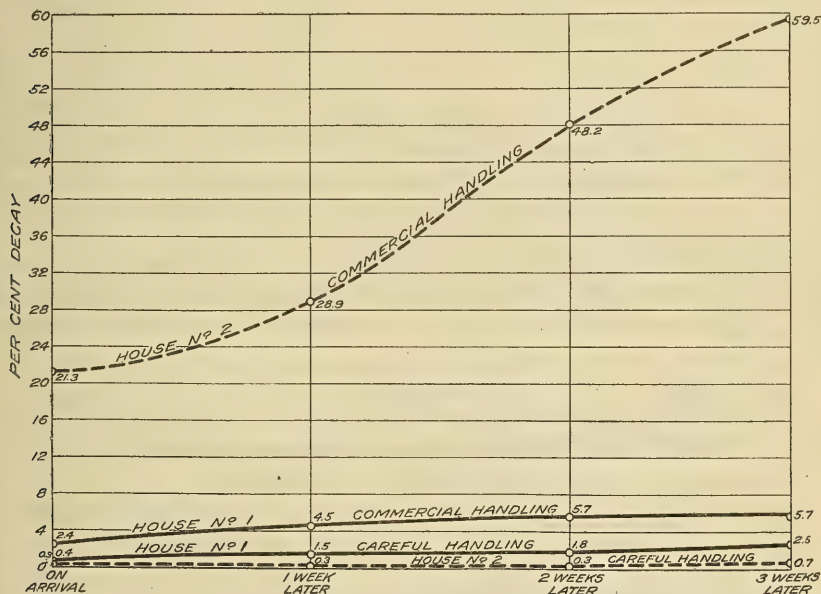


FIG. 21.—Diagram illustrating the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in carefully handled and commercially handled lots shipped from two houses in the same locality, 1910-11.

In house No. 1, where the type of handling was fairly good, the proportion of clipper cuts was 0.2 per cent; of pulled fruit, 1.6 per cent; and of long stems, 4 per cent. The immediate shipments of this fruit showed no decay on arrival, while the delayed lots had 3.7 per cent. After holding three weeks in market, 6 per cent and 8.2 per cent of decay developed in the immediate and delayed shipments, respectively.

TABLE XIX.—*Imperfections in picking and the percentage of blue-mold decay of commercially handled oranges on arrival in Washington and after holding for three weeks, from two houses in the same locality, 1911-12, showing the effect of careful handling on the carrying quality of fruit.*

Class of imperfections.	Picking inspections.	
	House No. 1.	House No. 2.
	Per cent.	Per cent.
Clipper cuts.....	0.2	7.4
Long stems.....	4.0	56.8
Pulled.....	1.6	.1

TABLE XIX.—*Imperfections in picking and the percentage of blue-mold decay of commercially handled oranges on arrival in Washington, etc.—Continued.*

Time of examination.	Experimental shipments.			
	House No. 1.		House No. 2.	
	Imme- diate.	Delayed.	Imme- diate.	Delayed.
	Per cent.	Per cent.	Per cent.	Per cent.
On arrival.....	0	3.7	8.0	19.4
After 1 week.....	1.5	5.2	12.0	23.0
After 2 weeks.....	2.7	6.7	15.6	27.4
After 3 weeks.....	6.0	8.2	22.4	34.5

In house No. 2, which was selected for rough handling, the percentage of clipper cuts was 7.4 per cent; of pulled fruit, 0.1 per cent; and of long stems, 56.8 per cent. The immediate shipments from this house showed an average of 8 per cent decay on arrival and the delayed shipments 19.4 per cent, these percentages being increased to 22.4 and 34.5, respectively, after three weeks in Washington.

The relationship between the type of field handling and the behavior of the fruit while in transit has been definitely established by numerous experiments during several seasons. The experiment cited above fairly represents the general character and results.

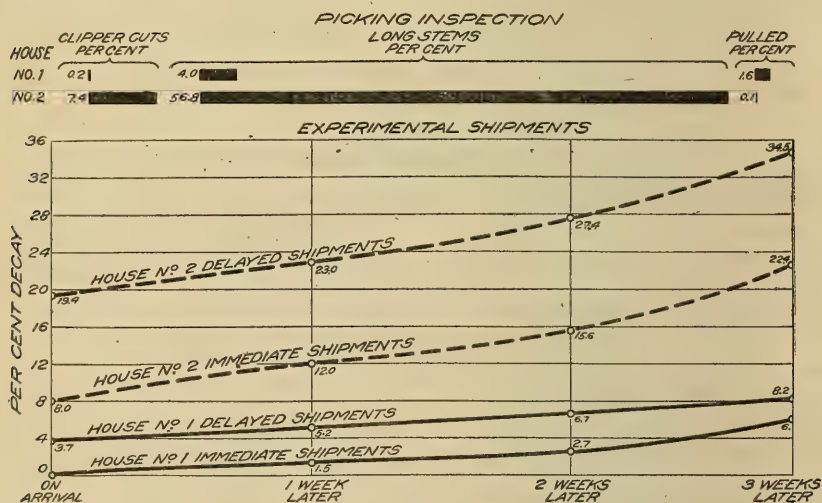


FIG. 22.—Diagram illustrating the percentage of imperfections in picking and the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in commercially handled lots from two houses in the same locality, 1911-12, showing the effect of careful handling on the carrying quality of the fruit.

The figures presented in Table XX and the accompanying diagrams (figs. 23 and 24) are shown to indicate the practicability of improving the handling and shipping conditions by giving special attention to the organization of the labor forces. The packing house from which the data were obtained was reorganized at the end of the 1910-11 season; the machinery was simplified and every effort was directed toward the introduction of better handling methods. Two experimental shipments were made—one during 1910-11 and one during 1911-12, two lots being sent out each season. The results of the inspections of the field work are given to show the great improvement in the second season, the results of careful handling by the bureau workers being also included for comparison with the commercial work done during the two seasons.

TABLE XX.—*Imperfections in picking and the percentage of blue-mold decay of fruit on arrival in Washington and after holding for three weeks, shipped from one packing house during 1910-11 and 1911-12, showing decrease in blue-mold decay due to greater care in handling.*

Class of imperfections.	Picking inspections.			Time of examination.	Experimental shipments.			
	1910-11		1911-12		1910-11 ¹		1911-12 ²	
	Jan. 17.	Mar. 3.	Dec. 13.		Careful.	Commercial.	Careful.	Commercial.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Clipper cuts....	11.3	5.7	1.8	On arrival....	0.2	8.0	0.3	1.1
Long stems....	23.0	11.9	10.4	After 1 week..	.6	12.6	.9	2.4
Pulled.....	1.0	5.1	1.4	After 2 weeks..	.8	15.3	1.2	2.8
				After 3 weeks..	1.3	15.8	1.5	4.1

¹ Fruit picked Feb. 1, 1911.

² Fruit picked Dec. 13, 1911.

It will be noticed that in 1910-11 (fig. 23) the total imperfections in the field handling amounted to 35.3 per cent at the first inspection and 22.7 per cent at the second. The average percentage of decay in the commercial shipments was 8 per cent on arrival at Washington, the carefully handled lots developing 0.2 per cent. In 1911-12 (fig. 24) the field work, while far from perfect, was considerably improved, the inspections showing 13.6 per cent of imperfections. The commercially handled fruit showed 1.1 per cent of decay on arrival, and the lots prepared by the bureau workers had 0.3 per cent. After holding the fruit in Washington for three weeks the commercially handled oranges developed 15.8 per cent of decay during 1910-11 and 4.1 per cent during 1911-12. When it is considered that the variation in the percentage of decay for these two seasons may easily mean a difference between profit and loss in the sale of the fruit from this house, the data presented become particularly impressive. It would be difficult to assemble a stronger array of facts

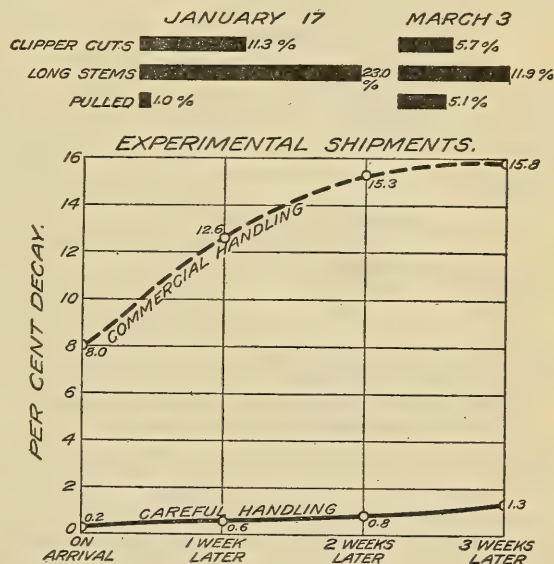


FIG. 23.—Diagram illustrating the percentage of imperfections in picking and the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in fruit shipped from one packing house, showing decrease in blue-mold decay due to greater care in handling, 1910-11.

than those brought together in this figure to illustrate the fundamental importance of preserving the sound carrying quality of oranges. The significance of the connection between field handling and the occurrence of decay during transit is definitely shown, as well as the practicability of improving conditions by means of more systematic management. This presentation should be sufficient to convince even the most skeptical that loss from decay in the shipment of Florida oranges is dependent upon the character of handling given the fruit in field and packing house.

RESULTS FROM A FINANCIAL STANDPOINT.

In order to emphasize the importance of careful work, the data may be analyzed from a financial standpoint. The results are perhaps more impressive when expressed in dollars and cents than when a statement is made regarding the percentages of decay in various lots of fruit.

The difference between the average percentages developed in the carefully picked and packed and the commercially picked and packed fruit during the season of 1910-11 was 6.4 per cent. This means that 1 out of approximately every 15½ boxes shipped during the season was unnecessarily destroyed by blue-mold decay, and that this loss might have been avoided if the fruit had been handled with care approximating that given by the bureau workers. It is only necessary to extend this line of reasoning. Out of every 100 boxes of fruit shipped, the avoidable loss was 6½ boxes; therefore, on a basis of 3,500,000 boxes of oranges shipped from Florida during the season of 1910-11 this loss aggregated 224,000 boxes, which at a fair f. o. b. price of \$1.50 per box gives a direct money loss of \$336,000.

In 1911-12 the difference in decay between the carefully handled and commercially handled fruit was 3.5 per cent, or a loss of 1 box for every 28½ boxes shipped. A fair

PICKING INSPECTION.

DECEMBER 13.

CLIPPER CUTS ■ 1.8 %.

LONG STEMS ■ 10.4 %

PULLED ■ 1.4 %

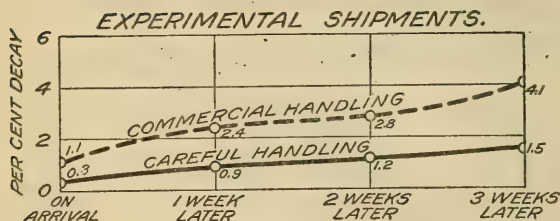


FIG. 24.—Diagram illustrating the percentage of imperfections in picking and the percentage of blue-mold decay of oranges on arrival in Washington and after holding for three weeks, in fruit shipped from one packing house, showing decrease in blue-mold decay due to greater care in handling, 1911-12.

estimate of the total shipment of oranges during that season is 3,750,000 boxes. The loss on this fruit, at the rate indicated, aggregates 131,250 boxes, which, figured at prevailing prices, may be valued at approximately \$200,000. Perhaps this is an exaggerated method of analyzing the true condition of affairs, yet when one takes into consideration the immense financial outlay necessary to pick, haul, grade, and pack these oranges, the actual money loss is not far from the amounts stated.

The figures stated above approximate the net loss to the growers due to decay. In addition, there is a large loss due to the cost of transporting and selling. According to statistics recently compiled, it costs from \$1.75 to \$1.93 to produce, prepare for shipment, and deliver in market one packed box of oranges.¹ With this cost as a basis, the losses reached the stupendous totals of \$432,320 during 1910-11 and approximately \$250,000 during 1911-12. From the standpoint of the effect upon the reputation of the Florida product the financial loss is even greater. It is impossible to give such a loss in actual figures, for the value of a reputation for high shipping and holding quality can not be estimated in dollars and cents. It is safe to say that the introduction of more careful methods would not increase the cost of handling to any material extent. No figures are available for such an increase, but the extra expense would certainly be only a small fraction of the actual money loss enumerated above. Leaving out of consideration the desirability of a good reputation, these figures should serve to convince those people who can appreciate values only from a financial standpoint that careful handling is necessary for the success of the industry.

¹ Statements of J. C. Chase and W. C. Temple before the Committee on Ways and Means, U. S. House of Representatives, 1913.

SEASONAL INFLUENCES ON THE OCCURRENCE OF DECAY.

It has been the general experience that blue-mold decay is more prevalent in Florida during the early months of the shipping season than it is later. Losses are most severe in December and January, the former month as a rule having the highest percentage of decay. So characteristic has this early deterioration been in the past that growers have become convinced that the underlying causes are not confined to improper methods of handling, and that the loss is due to some disease other than blue mold. Careful observation on the part of the bureau workers has shown this impression to be incorrect. An analysis of the circumstances under which fruit is handled during December shows that at that time of the year the conditions for the development of blue mold are particularly favorable. Rains are more or less prevalent and the humidity is generally high. It follows, therefore, that the type of handling which might suffice under favorable weather conditions will not then prove satisfactory.

In addition to bad weather conditions, the character of work done during the early part of the season is undoubtedly less careful than what is practiced later on. Shippers are in a hurry to get their fruit on the market in time for the holiday trade, and most of the workmen have not had sufficient experience. It seems impracticable, in Florida at least, to hold field and packing-house labor together throughout the year and to maintain a permanent organization. New pickers must therefore be trained each season, the same being true in the case of the packing-house labor, although probably to a less extent. These factors tend to lower the standard of early handling operations.

All the experiments made by the Bureau of Plant Industry emphasize the importance of systematic organization of the labor forces and careful handling of the fruit in every stage of its preparation for shipment. Every effort should be directed toward maintaining the fruit in sound condition from the time it is picked until it is unloaded at its final destination and placed in the hands of the consumer. During unfavorable seasons, frequent thorough inspections of the various operations through which the fruit passes are most essential. Instead of lowering the standard at this time, it is extremely important to approach the ideal as closely as possible.

In Tables XXI and XXII and figures 25 and 26, the percentages of decay occurring during the months of December, January, and February in 1910-11 and 1911-12 are presented. Table XXI and figure 25 show the decay in the carefully handled and commercially handled experimental shipments on arrival in Washington during December, January, February, and March, for both seasons. During December, 1910, the average percentage of decay in commercial shipments, on arrival at Washington, was 13.9 per cent. During December, 1911, the corresponding lots showed 9.4 per cent on arrival. The careful shipments during these months had 2.3 per cent in 1910 and 1.3 per cent in 1911, respectively.

TABLE XXI.—Blue-mold decay of oranges on arrival in Washington and after holding for three weeks, by months, in 1910-11 and 1911-12.

Time of examination.	Careful pick and pack.		Commercial pick and pack.		Time of examination.	Careful pick and pack.		Commercial pick and pack.	
	1910-11 ¹	1911-12 ²	1910-11 ¹	1911-12 ²		1910-11 ¹	1911-12 ²	1910-11 ¹	1911-12 ²
On arrival:	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	After 2 weeks:	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
December....	2.3	1.3	13.9	9.4	December....	4.3	2.1	21.6	14.1
January.....	.5	.6	6.8	4.0	January.....	1.6	1.4	14.5	10.1
February.....	.5	.2	6.2	1.6	February.....	1.4	1.0	12.4	9.6
March.....	.3	.....	5.0	.....	March.....	1.0	.....	8.5	.....
After 1 week:					After 3 weeks:				
December....	3.4	1.7	19.1	12.2	December....	4.4	2.8	22.2	17.2
January.....	1.1	.9	11.4	6.8	January.....	1.9	2.2	15.8	13.5
February.....	.9	.4	10.2	4.5	February.....	1.7	2.0	13.3	14.2
March.....	.6	.....	7.3	.....	March.....	1.2	.....	9.6	.....

¹ The figures for 1910-11 include 7 comparable shipments for December, 28 for January, 28 for February, and 16 for March.

² The figures for 1911-12 include 8 comparable shipments for December, 39 for January, and 18 for February.

Averaging the results for December, 1910 and 1911, the commercially handled fruit showed 11.6 per cent of decay on arrival and the carefully handled 1.8 per cent. During the months of January, 1911 and 1912, the decay of oranges shipped under commercial conditions was 6.8 per cent and 4 per cent, respectively. The corresponding carefully handled fruit showed 0.6 and 0.5 per cent, respectively, or practically the same for both years.

During February commercially handled fruit showed 6.2 per cent of deterioration on arrival at Washington in 1911, the percentage of decay for the following year being 1.6 per cent. The average of the February lots for the two seasons was 3.9 per cent. Carefully handled fruit during 1911 and 1912 arrived with 0.5 and 0.2 per cent of decay, respectively, the average for the two years being 0.3 per cent.

No experimental shipments were made later than February during the second season. In March, 1911, the average percentage of decay in commercial shipments was 5 per cent on arrival, the carefully handled lots showing only 0.3 per cent.

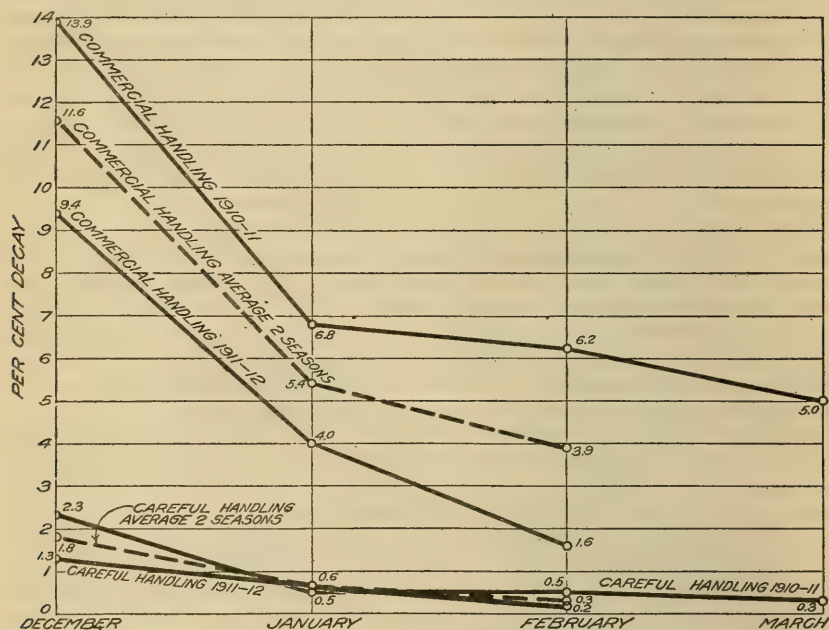


FIG. 25.—Diagram illustrating the percentage of blue-mold decay of oranges on arrival, by months, during two seasons, 1910-11 and 1911-12.

These figures are significant in that they show a very high percentage of decay during December, followed by a gradual decrease as the season advances. This is true for both commercially and carefully handled fruit, although in the case of the latter the loss was, without exception, below the usual 3 per cent commercial allowance. It is scarcely probable that decay can be held below this point even with the best system of handling, for it is practically impossible to eliminate every injured orange or to carry on the handling operations in such a way that absolutely no injury is done. The general principle that very slight injury will result in decay when weather conditions are favorable for the development of blue mold is substantiated by these figures, and the importance of extra care during the early months is again emphasized.

Table XXII and figure 26 show the average percentages of decay found in fruits shipped during December, January, and February, 1910-11 and 1911-12, on arrival at Washington and after holding for three weeks under ordinary market conditions.

TABLE XXII.—Blue-mold decay of oranges on arrival in Washington and after holding for three weeks; average of the two seasons, by months, in 1910-11 and 1911-12.

Time of examination.	Careful pick and pack.	Commercial pick and pack.	Time of examination.	Careful pick and pack.	Commercial pick and pack.
On arrival:	Per cent.	Per cent.	After 2 weeks:	Per cent.	Per cent.
December	1.8	11.6	December	3.2	17.8
January	.6	5.4	January	1.5	12.8
February	.3	3.9	February	1.2	10.5
After 1 week:			After 3 weeks:		
December	2.5	15.7	December	3.6	19.7
January	1.0	9.1	January	2.1	14.6
February	.7	7.3	February	1.8	13.8

The commercially handled fruit, picked and shipped during December, showed the highest average percentage of decay on arrival (11.6 per cent), and the increase after three weeks was correspondingly higher than was the case for fruit picked and shipped during January and February. Commercially handled fruit, picked and shipped during January, arrived with 5.4 per cent of decay, and that sent out during February showed 3.9 per cent on arrival. The shipments of carefully handled fruit arrived with an average of 1.8 per cent during December, 0.6 per cent during January, and 0.3 per cent during February, and after holding for three weeks showed 3.6 per cent, 2.1 per cent, and 1.8 per cent of decay, respectively. All of the carefully handled fruit, even that shipped during December, showed much less decay after three weeks in market than the commercial shipments during February showed on arrival. The superior shipping and market-holding qualities of carefully handled fruit are evident.

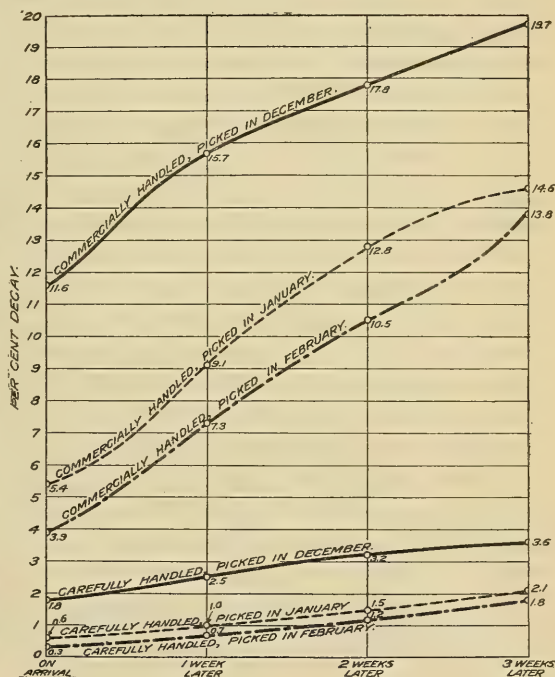


FIG. 26.—Diagram illustrating the percentage of blue-mold decay in carefully handled and commercially handled oranges picked during December, January, and February; average of the two seasons, 1910-11 and 1911-12.

PRECOOLING.

The term "precooling" has been used to designate the prompt and rapid cooling of fruit prior to shipment. The initial cooling of the product is accomplished very slowly when the fruit is shipped under ordinary icing conditions, the ice of a refrigerator car not being able to cool the fruit with sufficient promptness and rapidity to

prevent the development of decay. Consequently, deterioration is often far advanced before the temperature of the fruit is reduced to the point where these processes are checked. Under a system of precooling, the ice of the refrigerator car is relieved of the burden of initial cooling and is merely required to keep the fruit cool during transit.

Precooling is accomplished by means of special equipment, the refrigerating medium being either ice and salt or special refrigerating machinery. When adequate equipment is supplied, the initial temperature of the fruit may be reduced in a comparatively short time. The work may be done in refrigerated rooms or chambers before the boxes are placed in the cars, or it may be accomplished by circulating cold air around the packages after loading. The comparative advantages and limitations of these two systems can not be discussed here, but a few important points regarding the application of precooling to the shipment of Florida oranges must be emphasized.

Precooling may not safely be depended upon to offset decay following mechanical injuries due to improper methods of handling the fruit when preparing it for shipment. It is, however, a valuable and legitimate means of insuring arrival on the market in sound condition after each grower, packer, and shipper has done his share in properly handling the fruit. Precooling, in order to be effective, must be accomplished promptly and rapidly. A considerable delay in applying the process may nullify all possible benefits and defeat the object for which the work is undertaken.

Icing has been practiced to a limited extent in Florida, but precooling has not as yet been attempted. The value of this method of shipment in marketing Florida oranges is largely problematical. Its advantages are likely to be overestimated if the general distribution and application of the processes are attempted without careful and systematic investigation. During the warm and humid weather usually prevalent in Florida in December and January, precooling may be of considerable benefit, provided always that it is not expected to offset the bad effects of careless or improper handling. During warm and humid weather, such as occurred during the months of December, January, and part of February of the season of 1912-13, oranges are injured more easily than under ordinary conditions and are more subject to decay from these injuries. Infection from the ever-present, blue-mold spores is almost certain, and stem-end decay or other diseases may gain considerable headway. Rapid cooling (precooling) may possibly delay the development of stem-end decay for a week or more after the fruit arrives in market. While precooling and refrigeration can not do more than to delay for a short time the occurrence and development of this disease, such delay may prove of material benefit.

Precooling may reduce the quantity of ice consumed during the trip to market by removing the necessity of cooling fruit at the beginning of the trip. Possibly during the winter season, when the weather is cool or cold along the route, fruit which has been precooled may be moved to its destination under the initial icing alone. Precooling is expensive, and unless a material advantage can be obtained thereby its application can not be justified. If a sum of money equal to the expense of precooling is expended in insuring careful handling of the fruit during the course of its preparation for shipment, the returns will probably be more certain and more lasting.

STEM-END ROT.

In addition to the losses from blue mold, there has been considerable deterioration of Florida citrus fruits after arrival in market due to the attacks of the stem-end decay fungus. Unlike blue mold, this fungus does not apparently depend upon injuries or breaks in the skin through which to gain entrance to the tissues of the fruit. Investigation during the season of 1910-11, in cooperation with the Florida experiment station, proved conclusively that the stem-end rot disease can not be controlled by

means of careful handling. The results of this investigation into the nature of the fungus, its manner of growth, and its development have been published by the Florida experiment station.¹

SUMMARY.

The orange crop of Florida averages 4,000,000 or 5,000,000 boxes per year, and it has been estimated that, reckoning the good with the bad years, probably 10 per cent of the fruit decays before reaching the consumer. This entails an annual financial loss of at least half a million dollars. By far the most common form of decay is that caused by the growth of the blue-mold fungus within the tissues of the fruit, entrance being obtained only through some mechanical injury to the skin. The first researches of the Bureau of Plant Industry indicated that, owing to improper equipment in grove and packing house as well as to the carelessness of pickers and packers and their ignorance of the essential factors of good handling, considerable injury was being inflicted on the fruit in the course of its preparation for shipment. Most serious of all are the injuries inflicted by the clippers in severing the fruit from the tree and the punctures caused by the presence of long stems on the oranges. Many bruises or abrasions, especially those caused by dropping the fruit, can not be detected by packers and develop heavy decay in transit.

In most sections of the State cleaning the fruit has become a necessity, owing to the wide distribution of the citrus white fly and the development of the sooty-mold fungus which follows in the wake of that pest. At present probably 75 per cent of the Florida orange crop is cleaned either by washing or by the sawdust method. The Department investigations show that decay in transit or on the market is largely due to injuries received or aggravated during washing and drying and that these operations may be conducted in such a way that little or no harm ensues or may be followed by serious deterioration. The experiments of the Bureau of Plant Industry during the past seven years prove conclusively that the condition of the fruit after arrival in market depends largely upon the character of the work done in the grove and the packing house; that it is possible to so conduct the operations of picking, packing, and shipping as to inflict a minimum of mechanical injuries; and that uninjured Florida oranges can be placed on the market in practically sound condition even in seasons of very high decay. Practically all loss from blue-mold decay, such as has occurred in the past, can be eliminated.

The sizes of Florida oranges vary from 80 to 420 fruits in a box, the most common sizes being 126, 150, 176, and 200 to a box. The Florida shipping box measures 12 by 12 by 27 inches, inside dimensions, and has an estimated weight of 80 pounds when filled. The average shipment per car totals 321 boxes, loaded 2 tiers high. A standard shipping car is 33 feet long, 8 feet wide, and 84½ inches high; the minimum freight weight of a standard car of 300 boxes is 24,000 pounds. The average freight rate on citrus fruits from Florida during 1912-13 was 65.7 cents per box of 80 pounds weight.

During the past five years the Florida citrus industry has been reorganized and the changes have greatly improved the handling of the fruit. At the time the Department investigations were begun the methods of preparing oranges for shipment were extremely crude; there was no uniformity of system and the equipment was wholly inadequate to the needs of the industry. Of late years the old type of packing house has almost entirely disappeared. Modern houses, equipped with the newest machinery for handling fruit properly, have been constructed in practically every citrus district in the State, so that the industry is now well provided with the mechanical appliances for doing good work. Further reforms will include improvement of field equipment and more careful attention to the details of picking and to the organization

¹ Fawcett, H. S. Stem-end rot of citrus fruits. Florida Agricultural Experiment Station, Bulletin 106.

of the picking and packing crews. The men should be paid by the day instead of by the box, and a conscientious foreman should carefully oversee the work of the individual pickers. The bureau experiments prove that it is possible to train workmen to use more care and to greatly reduce their percentage of imperfections.

More than 90 experimental shipments of oranges were made from Florida in 1910-11, and 65 were sent out in 1911-12, including fruit from every section of the State and from good, poor, and average houses. Plate XV illustrates the condition in which some of these lots arrived in Washington. The carefully picked, graded, and packed fruit showed 4 per cent of decay on arrival, the commercially picked but carefully graded and packed fruit showed 35.6 per cent, and the commercially handled fruit had 65.9 per cent. After one week these percentages had increased to 4 per cent, 46 per cent, and 71.6 per cent, respectively; after two weeks they were 11.5 per cent, 54 per cent, and 72.2 per cent; and after three weeks, 11.5 per cent, 57.1 per cent, and 72.2 per cent.

The carefully handled fruit arrived in Washington during both seasons with less than 1 per cent of decay, or an average for the two years of 0.6 per cent for all the experimental shipments. The fruit handled under commercial conditions throughout had developed more than twice as much decay by the first inspection as occurred in the carefully handled fruit at the end of three weeks.

That commercial handling may also be careful handling is demonstrated by the fact that during both seasons the average percentage of decay in the commercial fruit shipped from 12 houses using care was almost as low as the average for any of the lots carefully handled by the bureau workers. In one packing house, where during 1910-11 the percentage of decay in the commercially handled fruit reached 15.8 per cent after holding for three weeks in Washington, the handling operations were so improved by the adoption of the bureau methods that during 1911-12 only 4.1 per cent of decay developed in the commercially handled fruit at the end of the same period.

It has been the general experience that blue-mold decay is more prevalent in Florida during the early months of the shipping season than it is later. All of the fruit carefully handled by the bureau workers, even that shipped during December, showed much less decay after three weeks in market than the commercial shipments during February showed on arrival. The shipping experiments showed that carefully handled fruit may be "cured" without serious loss, but that whenever the fruit has been appreciably damaged in the course of its preparation for shipment, decay is materially greater in the delayed lots.

Although not more than 1 per cent of the total shipments of citrus fruits had previously been iced, during 1912-13 a considerable number of commercial shipments were sent north under refrigeration. No systematic study was made of the behavior of fruit of the same grade and quality under the two systems of shipment, but the general opinion seems to prevail among shippers that the icing resulted in material benefit to the fruit. The investigations of the Bureau of Plant Industry have demonstrated, however, that Florida oranges may be transported to market under ventilation with a minimum loss from decay, even during periods of warm and humid weather, if sufficient care is used to preserve the skin of the fruit in an unbroken condition.

CONCLUSIONS.

In the light of the principles established by the workers of the Department of Agriculture in the investigations and experiments of the past seven seasons, viz, that the condition of the fruit after arrival in market depends largely upon the character of the work done in grove and packing house, and that it is possible to so conduct the operations of picking, packing, and shipping as to inflict a minimum of mechanical injuries

from which decay may develop, the following points are recommended to the attention of growers and shippers of Florida citrus fruits:

Workmen, especially pickers, should be paid by the day and not by the quantity of work done.

More careful attention to the details of picking and to the organization and inspection of the picking crews is necessary. Each member of the crew should be held responsible for the character of his work. An efficient field foreman should supervise the pickers, watch their output, and insist on careful handling. He should be prohibited from picking fruit himself.

Clippers with rounded or blunted points should be supplied. These should be frequently inspected by the foreman to prevent their becoming dull or loose at the joint.

Picking sacks of heavy material, which have partially closed mouths, allowing the fruit to be emptied from the bottom, and having a capacity of not more than half of a large standard field box, should be used.

Pickers should not pull the fruit from the tree. All oranges should be severed by means of the "double cut."

Fruit should be placed carefully in the picking sack and not dropped or tossed in.

The picking sack should be lowered into the field box and the oranges allowed to roll out gently without appreciable drop.

No fruit should be picked up from the ground and placed in the field boxes.

Smaller field boxes of lighter materials are recommended.

The fruit should not project above the top of the field box, and the latter should be transported to the packing house on a spring wagon. The driver should be given an especially prepared seat and not allowed to sit on the fruit.

Each picker and packer should be required to wear gloves.

Picking receptacles, field boxes, and packing bins should be kept free of gravel, twigs, splinters, protruding nails, or other foreign matter.

The efficiency of the packing house may be spoiled by a desire to save floor space. Simplicity should govern the choice and disposal of all equipment.

The desirable hopper is small, has padded sides, and allows the fruit to be emptied gradually by means of moving belts. The fruit should not fall by gravity at any stage of its journey.

Uniform and definite grading rules should be established for the State.

Wherever washing is not absolutely necessary in order to render the fruit marketable it should be omitted.

Water in the soaking tank should be frequently changed, and sprays of fresh water should be directed against the fruit as it passes through the washing machine.

The best type of washing machine has the fruit in plain sight at all times, allows no pressure on the oranges save that afforded by their own weight, does not allow the fruits to tumble over or against each other, and does not allow twigs, thorns, nails, etc., to become lodged in the runway through which the fruit must pass.

Fruit should never be packed while moist. An artificial drier in which a warm air blast is circulated around the fruit seems to be a necessity from the standpoint of thorough work and careful handling.

The sawdust method of cleaning grapefruit is ineffective as well as highly injurious.

Loose packs of fruit are more liable to be injured in transit than those of medium height with every orange firmly in place.

Decayed fruit should not be left in the boxes or allowed to accumulate on the floor or under the packing bins in the packing houses.

Curing is unwise, as the delay increases the chance for the infection of bruises or injured spots and facilitates the development of decay before shipment and in transit.

During unfavorable seasons, especially during December and January, when warm and humid weather is prevalent in Florida, frequent thorough inspections of the various operations through which the fruit passes are most essential. Instead of lowering the standard at this time, it is extremely important to approach the ideal as closely as possible.

Precooling may not safely be depended upon to offset decay following mechanical injuries due to improper methods of handling the fruit when preparing it for shipment, but it is a valuable and legitimate means of insuring arrival on the market in sound condition after each grower, packer, and shipper has done his share in properly handling the fruit.

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(PROFESSIONAL PAPER.)

POTATO WILT, LEAF-ROLL, AND RELATED DISEASES.

By W. A. ORTON,

Pathologist in Charge of Cotton and Truck Disease and Sugar-Plant Investigations.

INTRODUCTION.

During recent years there has been much doubt and misunderstanding among plant pathologists and observant farmers concerning the group of potato diseases variously referred to as wilt, leaf-roll, leaf-curl, Fusarium blight, bacterial ring disease, etc., which in different countries of the world appear to constitute problems of increasing importance to practical agriculture.

This bulletin seeks to clear up the situation and to open the way for more efficient measures of control by differentiating these previously confused diseases and fully describing the methods of diagnosis. The results afford a strong argument to pathologists for a broader outlook over the field and for international as well as national comparisons of conditions. The fundamental importance of thorough laboratory investigations is not minimized, but the interpretation of results in their relation to the basic principles of plant pathology and to the general problems of agriculture require a better conception of the different environmental influences to which crops are subjected in the several States and in foreign countries.

To the practical potato grower to whose attention these new potato diseases are brought, the feature of greatest significance will be their effects in impairing the vigor of his seed stock and on the deterioration of varieties. New evidence is presented that large but insidious losses have been suffered from seldom-recognized weaknesses in vegetative vigor and from diseases transmitted through the seed—losses that threaten to be greater in the future unless active measures are taken at once to secure more vigorous and disease-free strains or varieties through seed selection and breeding.

NOTE.—This paper is of interest to plant pathologists; it is suited to the potato-growing sections of the North, West, and South.

The more clearly this danger is made apparent to the growers and the more general and concerted their efforts to combat it the greater the likelihood that the final result will place the potato industry on a higher plane than it occupies to-day. The same system of seed selection and treatment and crop rotation that will free the potato fields of wilt, leaf-roll, and curly-dwarf will at the same time not only bring under control the blackleg and some other diseases, but will insure the maintenance of the strains cultivated in their most vigorous and productive condition and free from objectionable mixtures with other varieties.

Past experience warrants these statements. The history of potato pathology is a story of the gradual recognition and differentiation of previously confused diseases and the introduction of control measures that brought with them more progressive cultural practices. From about 1845 the late-blight, *Phytophthora infestans*, occupied the center of the stage and is still one of the most destructive diseases (Jones, Giddings, and Lutman, 1912).¹ It causes heavy losses in nearly all the potato districts of the world, especially in cool and humid seasons. In the United States, however, there are many sections where *Phytophthora* occurs somewhat rarely. An examination of a map prepared by Dr. Erwin F. Smith and published in the Annual Report of the Department of Agriculture for 1885 shows that the losses from late-blight and rot were even then recognized to be mainly in the northern tier of States. This has been confirmed by an annual plant-disease survey of the United States, which has been made during the past 12 years under the direction of the writer. This survey shows conclusively that *Phytophthora* as a common parasite of the potato is limited to the Northeastern States east of the Mississippi River, with only sporadic outbreaks in southeastern trucking regions, in the Puget Sound district, and occasionally elsewhere. This disease is now successfully combated by spraying with Bordeaux mixture, and it is to be expected soon that more disease-resistant varieties will introduce a new era of late-blight control.

To the southward it has been found that early blight, *Alternaria solani* (E. and M.) J. and G., and tip-burn play a greater rôle than *Phytophthora* in the injury to the potato crop. Early blight is apparently not so common in the cooler and more uniform climate of northern Europe. Nor does one find there that tip-burn is as common as here, where high summer temperatures combine with the injuries of flea beetles and other insects to cause excessive transpiration and its consequent marginal burning of the leaves. Here also the logical line of attack seems to be the production of varieties possessing heat resistance.

¹ All references to literature are indicated in the text by the name of the author and the year of publication. For full citations, see the list at the end of this bulletin.

With the progress of pathological studies, other diseases were recognized in the United States, some of which, like the southern bacterial wilt or brown-rot (Smith, Erwin F., 1896), had doubtless been long prevalent, if not actually endemic, in the United States, while others, like the blackleg (*Bacillus phytophthorus* Appel and related forms), appear to have been recently introduced into this country from Europe.

APPEARANCE OF NEW TROUBLES.

About 1904 there began to come into prominence a group of potato diseases hitherto not generally recognized as of economic importance. In that year there was published by Smith and Swingle a bulletin which described a wilt and dry rot due to *Fusarium oxysporum*, found in the District of Columbia, Michigan, and elsewhere. This was the first important work of the sort in the United States, though a disease that was very likely the same *Fusarium* wilt was mentioned by Clinton in 1895 as "bundle blackening of tubers." No mention was made of its relation to any disease of the plants, and it was considered "not a very serious malady." The cause was said to be a fungus "quite similar to" the one causing dry end-rot.

The disease described by Stewart (1896), and thought by Smith and Swingle to be probably the same, was stated by Prof. Stewart at a recent meeting of the American Phytopathological Society to be not due to a *Fusarium*.

In the year 1905 there occurred in Europe an outbreak of a disease which was named leaf-roll (Blattrollkrankheit). This recurred in 1907 with such virulence as to excite general alarm, and the attention of many pathologists and other agricultural workers was directed toward its study and prevention. Leaf-roll has continued to cause heavy losses in Germany, Austria, and elsewhere, though it has not become as generally destructive as was feared. Its nature remains a subject for debate. In the early years its resemblance to the American disease described by Smith and Swingle led to the general adoption of the theory that it was due to or associated with a *Fusarium*. The evidence on this point was very contradictory, and there have developed nearly as many opinions as there are investigators.

In America little was done after the work of Smith and Swingle until 1908, when an outbreak in an important potato district in California was studied by the present writer and found to be the same *Fusarium* wilt (Orton, 1909).

The writer continued his survey of the country in 1909 and 1910, finding the *Fusarium* wilt very widespread. In 1911 he studied potato diseases in Europe with the particular purpose of comparing the American *Fusarium* wilt with the European leaf-roll disease.

In the same year there occurred in eastern Colorado, western Nebraska, and adjacent districts a very serious outbreak of a potato disease which was at the time locally attributed to *Fusarium* (Fitch, C. L., in numerous newspaper articles).

The many discrepancies and confused points in the description of these diseases as presented in the European literature, in comparison with American conditions, were further cleared up by the study in 1912 of disease phenomena in a collection of seedling varieties grown in Maine and New York by Prof. William Stuart, of the Bureau of Plant Industry. Pure types of several of these troubles were presented, thus greatly facilitating their diagnosis and differentiation.

A visit to several other potato centers in Wisconsin, Minnesota, Colorado, Utah, Idaho, and California assisted in verifying the conclusions reached, which are given in detail in this bulletin.

Briefly stated, it appears that several distinct diseases have been confused to a greater or less degree by both American and European writers, and the widely differing opinions and results are due to the fact that none of the investigators had seen conditions in all the countries. In particular, the American and European troubles had not been compared.

In the present article several types of disease are to be distinguished as of some importance, at least in the United States, viz:

Fusarium wilt.—A disease characterized by the wilting or prematuring of the plant, accompanied by a browning of the vascular bundles of stem and tuber, which are infected by *Fusarium oxysporum* (Schlecht) Sm. and Sw. Widespread in America, but not yet identified from Europe.

Verticillium wilt.—A wilt resembling the foregoing, often more rapid and with fungus mycelium higher in the stem. Due to *Verticillium albo-atrum* Reinke and Berth. Described by Reinke and Berthold in 1879. Present in both America and Europe.

Leaf-roll.—An inheritable disease marked by rolling of the leaves, reduced yield, and other symptoms. Probably not due to a parasite. Common in Europe and lately appearing in America (Blattrollkrankheit).

Curly-dwarf.—An inheritable, nonparasitic trouble in which dwarfing of the vascular elements is a prominent characteristic. Found in Europe and America (Kräuselkrankheit).

Rosette.—A stunted or dwarfed condition of the potato associated with injuries of the underground stems and roots caused by the fungus *Rhizoctonia*; most conspicuous in the western United States.

Mosaic.—A pathological condition marked by a mottling and distortion of the foliage. Not previously described, but present in Europe as well as America.

It is not unlikely that future studies will enable us to add still other diseases to this group, and it may become convenient to differentiate more types of leaf-roll and of curly-dwarf from within the rather wide limits established in this paper.

The disease described by Appel as bacterial ring disease should be mentioned. It appears that in Germany this was formerly confused

with the leaf-roll group, but the writer has not seen this disease and has been unable to arrive at a satisfactory conclusion concerning its relationship to any known American trouble. The causal organism has not yet been properly described.

A second bacterial disease of German potatoes is referred to by Spieckermann (1911) as different from Appel's ring disease. This the writer saw at Muenster and found to be unlike any of the well-known American diseases.

FUSARIUM WILT.

DESCRIPTION OF DISEASED PLANTS.

The distinctive characteristics of this disease are a rolling or wilting of the leaves, premature death of the foliage, and the occurrence of the fungus *Fusarium oxysporum* (Schlecht) Sm. and Sw. in the lower part of the stem, in the stolons, and frequently in the tubers also.

In detail, the appearance of potatoes attacked by *Fusarium* wilt varies according to the severity of the infection, the age of the plants, and the variety.

The time of onset varies with the degree of infection. Where diseased seed stock has been used, there is often defective germination and an irregular stand of plants of uneven size. As a rule, however, the disease is not noticeable till the plants are a foot or more high, and in most cases it does not become generally prevalent till midsummer, while it is characteristic of moderate infections that the plants die only two or three weeks in advance of their normal time of maturity.

Wilting of the foliage is to be observed in the more rapid types of the disease, but is less marked than in some other *Fusarium* wilts, such as that of watermelon, for instance.

The name "wilt" has been retained because it is in common use for this and related maladies, though the name "*Fusarium* blight of potatoes" has also been applied. The foliage symptoms may be described by either term. They are those of a plant whose water supply has been gradually shut off by fungus invasion of the lower stem.

The lower leaves droop and die first, the upper ones wither or wilt, and the entire plant dies prematurely. (Pl. I.) The leaf-roll that accompanies wilt differs from the true leaf-roll in that the former lacks turgidity and the leaves die within a few days.

The color of plants in the first stages of wilt may be a lighter green than is normal. This frequently turns to yellow, especially if the progress of the disease is slow, when the entire plant becomes yellow and the field takes on a very spotted appearance. It is different with the true leaf-roll, where the yellowing is, in the American types, more confined to the upper leaves and is accompanied on many

varieties by reddish or purplish tones, which the writer has not observed with *Fusarium* wilt.

OCCURRENCE OF THE CAUSAL FUNGUS.

In the stem.—The lower portions of the potato stems show a brown discoloration, which extends throughout the underground portion and for several centimeters in the aboveground stems. The brown color is by no means as pronounced as in cotton wilt or in the *Verticillium* wilt of potatoes, nor does it extend upward through the whole stem and branches, as in the two other wilts mentioned. The *Fusarium* conidia are not formed in such abundance on dying or dead stems as those of other wilt diseases.

Microscopic examination shows the presence of mycelium in most of these browned stems, and cultures yield for the most part a single species of fungus (*Fusarium oxysporum*), though other *Fusaria* occasionally develop in advanced stages of wilt and bacteria as well, as might be expected in such moribund tissues. These other *Fusaria* have not been found to be uniformly associated with wilt, nor are they inhabitants of the vascular bundles, like *F. oxysporum*. A sharp distinction may be made between this typical and widespread wilt and the infrequent cases where other fungi which have entered through wounds or cracks have so injured the hypocotyl that a wilting of the foliage results. For example, Jamieson and Wollenweber (1912) produced a decay of potato stems followed by wilting of the foliage through inoculations with *F. tricothecoides*, but these writers do not believe or suggest that this fungus causes wilt in nature.

The amount of fungus in the vessels of the stem and the degree of discoloration varies, but not always in proportion to the effect on the life of the plant. It is not uncommon to find prematurely dead hills in infected fields which show comparatively slight vascular browning, while others remain living, yet when examined they prove to have both stems and tubers heavily infected with *Fusarium oxysporum*. This apparent resistance may be explained by the fact that such hills are either accidental admixtures of later varieties, or bud sports, called "run-out hills." In either case they are plants that remain in an active vegetative condition longer and thus resist the effects of the wilt. Still other hills are to be found which remain healthy till the normal time for maturity and are also free from fungus infection, thereby supporting the hope that resistant strains may be developed by selection. Unfortunately, the experiments have not yet demonstrated that these hopes can be realized, for all of the numerous selections made were attacked by wilt the following year. This work was done at Middle River, Cal., in 1909 and 1910, principally with the Burbank variety.

In contrast with the slow-developing cases described, one finds many hills where there is actual wilting and rapid death of the plants, due to the water supply having been cut off by the fungous mycelium in the vascular bundles. Weekly examinations of fields during August and September show that the plants are dying prematurely and in increasing numbers as the season advances.

It will be brought out later in describing leaf-roll that the latter does not cause such a rapid and early death as the wilt, but that plants showing distinct symptoms of leaf-roll in June may live till harvest time.

In the root.—The fungus appears to enter through the smaller roots, and there are some indications that its injuries to the feeding roots are the cause of the dwarfed and checked development of the plant during the early stages of the disease. As a result of partial destruction of the roots, the plants are easily pulled up, and the roots are partly dead and brittle. As Smith and Swingle (1904) write:

All the smaller roots are so friable that they can be broken with almost no effort, and some can even be rubbed to pieces between the thumb and finger. The main root also is much more tender and brittle than that of healthy plants, and this condition extends nearly to the line marked by the surface of the ground. Such diseased roots are usually covered with a white, pink, or even reddish growth of mycelium, which is distributed very unevenly and is much more conspicuous in some places than in others. Microscopical examination shows that this mycelium invades all parts of the root, though the bark is most affected.

It is possible, and from some recent observations it seems quite likely, that some of this root injury is due to secondary invasion of other species of fungi.

The underground stems on which the tubers are borne are nearly always attacked, but they do not as a rule become so soft and brittle as roots of the same size. The mycelium passes through the whole extent of these underground stems into the base of the tubers.

In the tuber.—The infection of the tubers by the *Fusarium* is in well-marked cases almost universal. This is evidenced by the distinct browning of the vascular ring shown when tubers are cut across at the stem end (Pl. II, fig. 1). From these browned vessels *Fusarium oxysporum* can readily be isolated. To quote again from Smith and Swingle (1904):

Numerous cultures made from the extreme ends of the discolored portions of the bundles very seldom failed to develop the fungus. These cultures were made by carefully paring especially favorable pieces of diseased tubers with a hot scalpel, heating it nearly to redness before each stroke and cutting out pieces a few millimeters in diameter, containing a length of about two millimeters of the extreme end of the discolored part of the bundle. These pieces were cut from the main part of the specimen with the hot scalpel and allowed to drop directly into a tube of sterile culture media. Potato cylinders were used principally for media. Slant tubes of beef agar (+15 on Fuller's scale) also were sometimes used. One hundred and twenty-two

cultures on potato and sixteen on agar were made, and in all but two cases on the potato and in every case on the agar the fungus appeared after a day or two as a white mycelium, sparse at first, growing directly out from the blackened bundle, and spreading into the media. Forty-two cultures on potato and four on agar were also made from older parts of the discolored ring nearer the basal end, and of these all but one on the potato and all on the agar produced a growth of the fungus.

The relation of these tuber infections to stem-end dry-rot will be described more fully in another publication. A dry-rot of the tuber was considered by Smith and Swingle to be caused by the same *Fusarium* which produces the wilt of the foliage, but the recent studies of Wollenweber (1913) have shown that *Fusarium oxysporum* is a vascular parasite causing wilt and wintering over in the tubers, where it produces a stem-end vascular discoloration, but no decay. Tuber dry-rot is caused by one or another of the following fungi, which follow *F. oxysporum* or infect through wounds, viz: *F. coeruleum* (Lib.), *F. triotheioides* Wr., *F. discolor* var. *sulphureum* Schlecht, *F. ventricosum* App. and Wr.; and probably sometimes also the less parasitic *F. gibbosum* App. and Wr., and *F. subulatum* App. and Wr.

SOIL RELATIONS OF FUSARIUM WILT.

The *Fusarium* wilts of cotton, watermelon, and cowpea occur principally on sandy and sandy-loam soils and are practically restricted to them. That such is the case with the potato wilt is by no means clear, though there is evidence indicating that light soils are more liable to infection. The California tule lands, where wilt is perhaps more prevalent, are reclaimed and artificially drained peat islands, with a very light and friable soil, composed almost wholly of organic matter. In Oregon, Utah, and Colorado, however, wilt occurs on heavier soils, varying from sandy loam to clay loam. Potatoes thrive best in light, deep, and well-drained fertile soils, and it appears that the wilt is more likely to develop in any such good potato soils than under conditions unfavorable to the crop.

THE PARASITISM OF FUSARIUM OXYSPORUM.

That the fungus *Fusarium oxysporum* is parasitic upon the potato plant has now been proved with reasonable certainty. Smith and Swingle established the fact of its constant occurrence in the vascular tissues of plants suffering from the wilt disease, by means of very numerous pure cultures. No inoculation experiments were undertaken by them, but successful infections have since been reported by Manns (1911) from the Ohio Agricultural Experiment Station, and cultures of the Ohio strain have been studied by Dr. H. W. Wollenweber in comparison with a large number of others isolated from collections made by the writer from different parts of the United States or sent in by correspondents, and nearly all have proved to be the species we continue to call *F. oxysporum* Schlecht.



POTATO FUSARIUM WILT. A FRESHLY WILTED PLANT. (AFTER SMITH AND SWINGLE.)

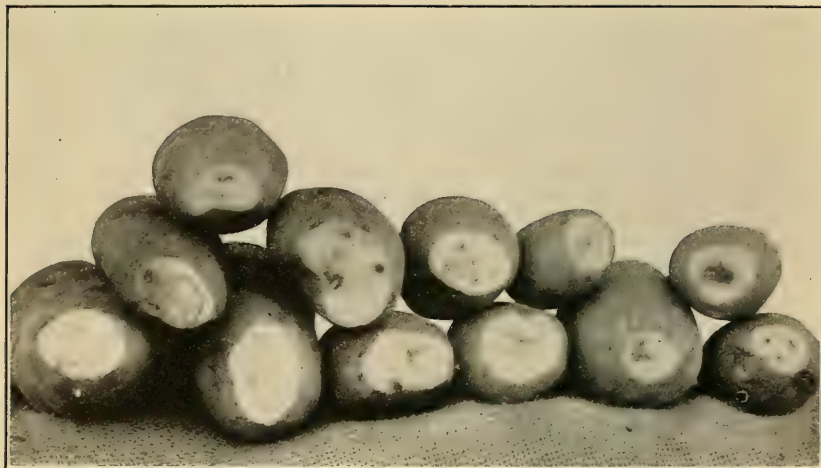


FIG. 1.—STEM-END BROWNING OF POTATOES DUE TO *FUSARIUM OXYSPORUM*. TUBERS FROM WILTED PLANTS, BURBANK VARIETY, MIDDLE RIVER, CAL.

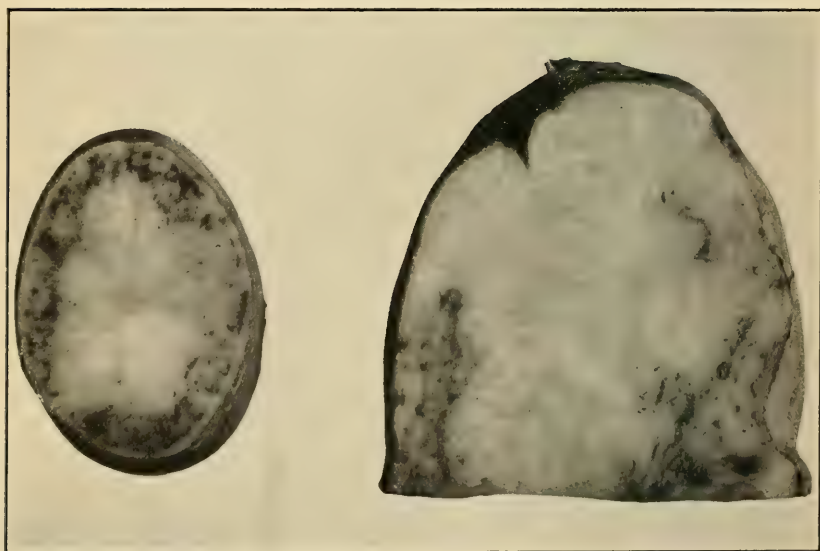


FIG. 2.—NET NECROSIS OF POTATO, SHOWING NONPARASITIC INTERNAL DISCOLORATION OF TUBERS.

The point of view toward the genus *Fusarium* has changed greatly since 1904. At that time Smith and Swingle reviewed all species of *Fusarium* that had been described as occurring on the potato and concluded that as far as the description went it was impossible to distinguish these from each other or from the cause of wilt. They therefore took the oldest name, *Fusarium oxysporum*, for their species and considered the others, including *F. solani*, to be synonyms. A little later, when the relation of *Fusarium* to leaf-roll was taken up by Dr. O. Appel, of the Kaiserliche Biologische Anstalt in Dahlem, Berlin, he caused to be inaugurated some morphological studies based on his conclusions that, up to the present, mycologists had not described *Fusarium* species in a way that permits their reidentification; that the insufficiency of the characters utilized for systematic description had led to a widespread belief that the genus was exceedingly variable, and that they had been differentiated by their host or substratum to too great an extent.

Appel therefore concluded that before a proper study of *Fusarium* diseases could be made it would be necessary to learn more about the fungi and to be able to distinguish the species with certainty through their morphological characters. Much progress has been made in this direction through the work of Appel and Wollenweber (1910), whose monograph has laid the foundation for the separation of the species by their morphological characters. Further publications by Dr. Wollenweber have thrown still more light on this hitherto confused problem. (Wollenweber, 1913.)

It has already been found that the *Fusaria* are not so variable as was formerly thought. Artificial cultures lend great help in the work of identification, in which many characters are utilized which had been previously neglected, viz: The character of the curvature of the conidia, constancy of septation, development of the basal and apical cells of the conidia, etc.

It has also been shown that the pure cultures must be grown on such media as will produce a normal development of the fungus. Agar, for instance, is poorly adapted for the culture of *Fusaria*, as it tends to produce constricted conidia. Vegetable media are best, as a rule, and many plant stems are especially favorable for the development of conidia and sporodochia in a normal manner.

A culture derived from mycelium gives a less normal culture than one from conidia and must be grown till spores are produced to start new and typical cultures. Young cultures are not favorable for morphological study, as they contain many abnormal forms. Neither are old cultures good, as they exhibit hunger forms not typical of the species.

For these reasons many substrata must be tried and the cultures grown to their best development, designated by Dr. Wollenweber as

a "high culture." Color differences of both spores and mycelium are to be noted, and for the latter purpose potato cylinders and rice are excellent.

The final result of this line of work will be a great simplification of the *Fusarium* problem. The number of species in the genus will be diminished and the parasitic forms can be identified, for the most part, by their morphological characters. It has been found that the genus is divisible into sections, on the basis of form of conidia and other morphological characters, and that all of the wilt parasites are included in the single section, *Elegans*. Thus far *Fusarium oxysporum* appears to be the only *Fusarium* causing potato wilt; and, as already stated, this is not connected with the dry-rot of tubers, which may be due to one or another of four or more other *Fusaria*. The diagnosis of these tuber troubles will be treated more at length in another publication.

CLIMATIC RELATIONS AND GEOGRAPHIC DISTRIBUTION OF FUSARIUM WILT.

Fusarium wilt is apparently a disease of warmer climates. States like California and Arizona, with high summer temperatures, and the middle States, Ohio, Missouri, and Nebraska, which are near the southern border of profitable main-crop potato culture, suffer much more than the States of the northern border, where wilt is, at least, uncommon. Most of the *Fusarium* wilt diseases of other crops are southern in their range. Owing to the fact that other species of *Fusarium*, such as *Fusarium coeruleum* and *F. discolor* var. *sulphureum* also occur in the Northern States and have not hitherto been clearly differentiated from *F. oxysporum*, there is some doubt as to the actual range of the latter, especially in New York and New England. Going westward, the wilt fungus is found farther north, and it is likely that the disease will continue to spread northward.

In the States from New Jersey and Maryland southward to Florida and westward to Texas the Irish potato is relatively a minor crop, except in the trucking districts, where planting takes place in winter or early spring, and the harvest for the northern markets occurs from April to July, generally in advance of maturity. *Fusarium* has never played a visible rôle in these early crops, but has been found in the second or fall crop.

As already stated, New England and New York are relatively free from the disease. Suspected cases there have generally proved to be the *Verticillium* wilt. The conditions in Pennsylvania are not as well known to the writer, but are probably not far different from those in Ohio, where Selby and Manns have found wilt to be widely distributed. The latter says:

In this *Fusarium* blight we have the most persistent and destructive disease factor with which the Ohio potato grower has to contend. Its subtle work in the past, though

greatly reducing our yields, has been entirely overlooked. The seed potatoes throughout Ohio are infected to a much greater extent than would have been supposed. This indicates that much of our potato land is already carrying the fungus to a greater or less amount, and as a result our yields are probably being reduced considerably. (Manns, 1911.)

The writer has found many Michigan fields infected with wilt. The original material studied by Dr. Erwin F. Smith also came from this State. In Illinois and southern Wisconsin and in Minnesota wilt appears to be present in the older communities, where potatoes have long been grown, but in the newer districts of Wisconsin and Minnesota the growers still have an opportunity to protect themselves against this danger.

There are important potato districts in western Nebraska where *Fusarium* wilt occurs, although the leaf-roll and the powdery dry-rot (*Fusarium trichothecioides*) are also factors there. (Orton, 1913.) All the older irrigated districts of the West are infected, and the newer ones are rapidly becoming so, with the possible exception of the higher and cooler valleys, concerning which definite information is lacking at present. The wilt has been long present in Colorado and caused much injury, especially when attempts were made to grow two or three successive crops of potatoes. In Utah it is much the same, and the newly opened districts in Idaho are rapidly introducing the fungus in seed potatoes brought from older localities. Nor is the wilt confined to the irrigated parts of the West. It also occurs on the "dry farms," and is not the least of the problems which the settlers in these areas have to solve. The potatoes at the field station of the Bureau of Plant Industry at Akron, Colo., have been attacked by wilt for several years and the yield much diminished.

It is, however, in potato growing under irrigation that wilt plays the largest rôle. These lands are all high priced, from \$200 an acre up. The farmer has to carry fixed charges in the way of interest, water rents, irrigation bonds, and the like that make it necessary for him to grow a crop more remunerative than grain or alfalfa. Sugar beets and potatoes are, in most cases, the only crops that answer this requirement in these districts. The farmers naturally desire to grow potatoes as frequently as possible, but are prevented from doing so by the wilt, which forces a rotation.

In California wilt is the principal factor limiting the production of potatoes in the famous delta district of the San Joaquin Valley. (Orton, 1909). Here the reclaimed moor, or tule, soils are wonderfully productive when first planted, but the yield of potatoes falls off with each succeeding crop until very small yields are secured unless rotations with barley or other crops are practiced. The potatoes from these diseased fields show almost universal infection with *Fusarium oxysporum*, which is there the principal, if not the

sole, cause of the early maturity and diminished harvests. This tule land for potatoes commands a cash rental of \$20 to \$25, while for barley growing only \$8 to \$12 is paid, but after the second crop of potatoes the less profitable crop must intervene (Irish, 1913).

One of the leading potato districts north of California is the Willamette Valley, in Oregon. Here wilt is present to a serious extent. During visits in 1909 and 1910 the writer saw fields liberally dotted with yellow and dying plants. This valley furnishes most of the seed potatoes brought into California, and inspection of such potatoes has revealed much stem-end browning.

It is certain that the *Fusarium* wilt is a nation-wide problem and one that will have a marked influence upon American agriculture. At present it causes losses which probably run into millions of dollars; but, if in the end the growers are forced to adopt better rotation systems, who shall say that the final influence of this disease factor may not be beneficial?

Estimates of the money losses from *Fusarium* wilt must be largely speculative, as so little exact information is available. At the Ohio experiment station in 1909 the result of the disease was that "the station plats averaged 69 bushels per acre and the county averaged 186 bushels. The preceding 4-year average for the station was 180 bushels, while that for the county was 101 bushels." The county was also infected with wilt, as the same writer shows; but, disregarding this and the fact that the station yield should have been nearly double the county yield, and estimating that only 5 per cent of Ohio fields were as badly affected, the loss totals over 870,000 bushels for Ohio alone.

CONTROL OF FUSARIUM WILT.

The problem of control has not yet been worked out for *Fusarium* wilt. The most promising lines of attack are three: (a) A healthy seed supply, (b) rotation of crops, (c) the development of resistant varieties.

The use of *Fusarium*-infected seed should be avoided even where the disease is already in the land. It not only increases the severity of the wilt trouble, but gives defective germination. Failures due to decay of the seed potatoes after planting are especially frequent in the West, as, for example, in Colorado in 1908 and in California in 1912. These are attributed to *Fusarium*, but the recent studies of Wollenweber show that *Fusarium oxysporum* does little more than lower the vitality and afford an entrance for other organisms which destroy the seed potatoes after planting. *F. trichothecioides* in the West and *F. coeruleum* in the East are the best known of these tuber-decay producers. To what extent other organisms are involved remains to be determined.

TESTS FOR FUSARIUM INFECTION OF SEED POTATOES.

The most effective method of selecting seed stock free from wilt is to examine the fields where it is being grown as late as possible in the autumn, but before the foliage has died down or been frosted. The wilt is more readily detected at this time than at any other through the premature ripening or actual wilting which it causes, coupled with the characteristic brown discoloration of the woody part of the lower stem.

Another indication much relied on is the browning of the vascular ring shown when the stem ends of the tubers of diseased plants are cut off. (Pl. II, fig. 1.) This is an important test to apply, and it is an excellent rule to reject for planting purposes all lots of potatoes any considerable number of which show such a ring discoloration, as some other diseases produce a similar effect.

It is desired to emphasize here, however, that not all tubers from infected fields show stem-end browning. The writer has hundreds of times observed tubers from wilted hills which showed no discoloration or only a very slight one. The fungus had apparently not gone far in its usual course down the stolons and into the tubers, yet the fields were thoroughly infected, and the circumstances warranted grave doubts as to the value of such tubers for planting. It is probably inadvisable to endeavor to select, for seed purposes, from stock containing a large percentage of infected potatoes, any fungus-free tubers on the basis of this stem-end test when it is at all feasible to secure for planting potatoes entirely free from suspicion. As a practical farm procedure, however, growers should be urged to discard all stem-end pieces which show any brown stain, and it is likely that the greater part of the infection would be avoided if the stem ends of the seed tubers were cut off and not planted.

Some confusion may result in the application of this stem-end browning test by those unfamiliar with the subject, on account of difficulty in distinguishing in certain cases a natural browning in many potato varieties, like Irish Cobbler, for example, which have a deep depression at the stem end into which the stolon fits. The cork layer in these varieties may be bared by a shallow section through the stem end and show a brown color quite natural to the variety.

It is necessary to cut deep enough to reach below the point where the vascular bundles diverge from the stolon to form the tuber ring. Any browning at this point is highly suspicious, but not positive proof. The weakening of the plant by leaf-roll or other diseases may hinder the formation of a cork layer at the stem and permit the entrance of saprophytic fungi which produce a discoloration. The discussion of this point in the European literature on leaf-roll will be of interest.

That parasites other than *Fusarium oxysporum* also produce stem-end browning has already been mentioned. *Verticillium albo-atrum* can often be differentiated by an experienced eye by the blacker and deeper discoloration, though the plant symptoms give a better basis for the diagnosis of this disease also. A stem-end browning is found in the late stage of blackleg, *Bacillus phytophthorus* Appel, etc., and of brown rot, *B. solanacearum* Erw. Sm., diseases hardly less dangerous than wilt.

Mention should also be made of a form of internal browning that has been known to the writer for five or six years. It may be confused with *Fusarium* ring discoloration, though it is probably more closely related to the physiological trouble, internal brown-spot. The term "net necrosis" has been suggested for the disease by Dr. H. W. Wollenweber. It is characterized by the occurrence of narrow streaks or dots of browned tissue outside of the vascular ring and extending from the stem end into the tuber for a considerable distance or entirely through it. (Pl. II, fig. 2.) These brown tissues are free from fungi or bacteria. The cause is unknown. A fuller description will be published soon.

The final conclusion of the writer on this point is that tuber-ring discoloration, if clearly marked, should cause the rejection of potatoes for seed purposes, but that negative results from cutting tubers are less valuable as proof of freedom from wilt than a field inspection in autumn. A system of official certification of freedom from wilt and other diseases would be of great value, if based on such field observation.

SOURCE OF SEED POTATOES.

In all probability, the best seed for areas possessing a climate where potatoes retain their vigor without renewal for long periods, is that of the home locality. In many districts, however, and particularly those in the Central and Southern States, it is necessary to bring in seed from northern sources. Many western districts seem to have the same need, particularly those where *Fusarium* wilt already prevails, and have not yet discovered a source of seed as satisfactory for them as New England seed is to the South. There must be developed somewhere in the West communities where growing seed potatoes will be a special industry and where every means will be taken to produce a perfectly healthy article. The accomplishment of this aim well merits attention from a cooperative association of buyers and seed growers.

CONTROL OF WILT THROUGH ROTATIONS.

Rotation of crops appears to be the most effective means for lessening the injuries from *Fusarium* wilt. What is known regarding the effect of rotation is from observation and general farm experience

rather than the result of definitely planned and carefully controlled experiments. There is great need for such experiments.

In the San Joaquin district of California the principle is found to be established that potatoes yield better after rotation with barley. In no case known to the writer has the *Fusarium* wilt been eliminated by rotation, but it seems that the amount of infection diminishes after a few years to a point where a potato crop can again be grown. In Ohio a 3-year rotation was not sufficient to prevent a general epidemic on the station plats.

A rotation of five to eight years could, however, be readily practiced in all districts, except those where the potato is the sole money crop, and it is believed that such a rotation would make the losses from wilt negligible.

The infection of the ground through potatoes left in digging is a factor to be considered, and in warm climates like California, where such potatoes grow as volunteers for one or two seasons or longer, the disease is steadily carried over. Some means of ridding the land of such potatoes seems necessary.

RESISTANCE OF VARIETIES TO WILT.

The results of variety tests of potatoes to date offer hope that the future may give sorts resistant to *Fusarium* wilt, but there are none at present that can be recommended as adapted for commercial cultivation. There are now under trial in the Bureau of Plant Industry several thousand seedlings, the best of which will later be tested for resistance to this disease.

EFFECT OF FERTILIZERS ON WILT.

Smith and Swingle made rather extended experiments on the effect of fertilizers on wilt, with results that were entirely negative. Nothing has since been observed that would materially support the suggestion that the disease may be connected with a deficiency of any element of plant food. It occurs in some of the richest western soils, both irrigated and nonirrigated. In California the soils were almost pure organic matter, and the reduction in yields that followed the appearance of wilt was at first attributed to soil exhaustion, but the fungus factor is fully sufficient to explain the results, and fertilizer experiments that were made by the writer gave negative results. Further work along similar lines has been reported by Irish (1913).

QUARANTINE MEASURES.

In connection with the seed problem, there comes into consideration the desirability of keeping the disease out of those districts where it does not yet occur. Does this warrant quarantine restrictions by State or Federal authorities? Would such a quarantine be effective?

It is the writer's opinion that under present conditions this is not a quarantinable disease. It is very widely distributed in the United States, as already shown. It would be difficult to establish the boundaries of infected areas, and almost impossible to apply quarantine restrictions without serious injury to commerce. Nor is it certain that the aim desired would be accomplished in this way. There are so many avenues for the spread of plant diseases that it often seems as if only ocean barriers were of avail. (Lounsbury, 1909, 1910.)

OCCURRENCE OF AMERICAN FUSARIUM WILT IN EUROPE.

The bulletin by Smith and Swingle had its influence on European pathology, inasmuch as the leaf-roll epidemic, which began in 1905, was at first believed to be a *Fusarium* disease. The fact that none of the European workers had seen the American disease and that no American pathologist familiar with wilt had seen the leaf-roll in Europe led to further confusion.

The writer now believes that there is no evidence that the American wilt disease occurs in Europe. This statement is based on observations made in the course of a study trip through Germany, Austria, and England in 1911. No cases of typical *Fusarium* wilt were seen. Furthermore, Dr. Wollenweber, in the morphological studies later mentioned, has been able to differentiate the *Fusarium oxysporum* of Smith and Swingle from other potato *Fusaria*, and he finds this to be distinct from any European form. Inasmuch as he studied critically the *Fusaria* isolated from leaf-roll material while at Dahlem, Berlin, this result is very significant and goes far to explain the difficulty German workers have had in verifying the observations of Smith and Swingle. Himmelbaur (1912) reports *Fusarium* to occur in much of the leaf-roll material studied by him in Austria, but he has not identified the species, and until this is done his results can not be correlated with the results of American workers.

VERTICILLIUM WILT.

DESCRIPTION OF THE DISEASED PLANTS.

The *Verticillium* wilt of potatoes is characterized by a wilting or blighting of the foliage, resulting in the premature death of the hill. The vascular bundles of the stem, the stolons, and usually of the tubers, are filled with the mycelium of *Verticillium albo-atrum*. The spores of this fungus often cover the dead stalks, so that they become conspicuous from their gray color.

As observed by the writer in this country and in England in 1911, plants attacked by *Verticillium* wilt generally die quickly. There may be yellowing of the foliage, but the drooping and wilting has been pronounced in most of the cases observed. The *Verticillium* wilt



VERTICILLIUM WILT OF POTATOES IN GREENHOUSE. CENTER AND RIGHT-HAND PLANTS INOCULATED WITH PURE CULTURES OF *VERTICILLIUM ALBO-ATRUM*; LEFT-HAND PLANT HEALTHY, NOT INOCULATED.



FIG. 1.—TYPICAL POTATO LEAF-ROLL IN SEEDLING NO. 16472, ALEXANDER NO. 1
RED X KEEPER. HOULTON, ME., AUGUST, 1912.



FIG. 2.—POTATO LEAF-ROLL. ADVANCED STAGE IN SEEDLING NO. 304, GEHEIMRAT
THIEL X KEEPER. HOULTON, ME., AUGUST, 1912.



POTATO LEAF-ROLL. PLANTS OF SEEDLING No. 2171, SOPHIE X KEEPER. HOULTON, ME., JULY 29, 1913.



POTATO LEAF-ROLL, SHOWING ENTIRE ROW, NO. 2171, SOPHIE X KEEPER, STRONGLY AFFECTED, WITH ROW NO. 2165 (AT THE RIGHT) AND OTHER ADJACENT ROWS HEALTHY. HOULTON, ME., JULY 29, 1913.

seen in Germany appears to be slower in causing the death of the plants, a difference possibly attributable to temperature and rainfall factors. The browning of the vessels is also marked, often extending to the tips of the stems and into the leaf petioles. There has been also a pronounced discoloration of the stem end of the tubers in all the cases observed.

Verticillium wilt is often not strikingly different from Fusarium wilt in outward appearance, though it may induce a more rapid wilting. The presence of the mycelium and vascular browning in the upper portions of the plants is indicative of Verticillium, as Fusarium does not usually extend into the tips of the stalks. The profuse production of conidia on the stalks, often before they are entirely dead, is still more characteristic. The stain in the stem end of the tubers is blacker, and in cross sections under the microscope the vascular bundles are found to contain hyaline mycelium smaller than that of *Fusarium oxysporum*. The final proof of the identity of the disease comes, of course, when cultures made from the internal mycelium yield *Verticillium albo-atrum*.

So far as observations go, Verticillium wilt occurs in scattered hills here and there over the fields. The destruction of entire crops, such as is frequently caused by *Fusarium oxysporum*, has not been seen.

GEOGRAPHIC DISTRIBUTION.

Verticillium wilt has been collected by the writer since 1909 from the State of Washington (La Conner) to Maine, but only in the more northern States. It has been seen in Vermont (Franklin County) and western New York, but in neither case in abundance. The varieties most attacked were Factor and Up-to-date, from seed originally from England. It is believed that the Verticillium infection came with the seed potatoes. The same fields planted to other varieties in 1913 were free from wilt on August 1 and 4.

The writer collected the same disease in Olmskirk, England, September 11, 1911, and the fungus was isolated from a tuber (said to have come from Scotland) found in Reading, England. Its occurrence in Ireland is vouched for by Pethybridge (1911). It appears to be common in Germany, judging by the frequency with which it is mentioned in connection with leaf-roll investigations there. Indeed, it was described by Reinke and Berthold as long ago as 1879, and the writer saw it at Munster in Westphalia in October, 1911, where it was studied by Spieckermann (1911), who pointed out the difference between this wilt and the fungus-free leaf-roll. Verticillium wilt is apparently a northern disease as compared with Fusarium, though the ranges of the two undoubtedly overlap.

Pethybridge (1911) in Ireland describes this disease under the name "leaf-roll," distinguishing it from "curl," the latter being the

trouble here described as "curly-dwarf" (Kräuselkrankheit). He emphasizes the rolling of the leaves, but does not mention that they wilt. The discoloration of the vascular bundles of stem and tuber is remarked, and experiments are cited which show that the disease is transmitted through affected seed tubers.

The same author (1912) further illustrates the distinction between curly-dwarf ("curl") and leaf-roll, and reports having found cases of leaf-roll in which no *Verticillium* or other fungus was present. Tubers from such plants gave rise to healthy plants, whence it is concluded that the occurrence of the true leaf-roll in Ireland is not yet established.

These facts, together with his personal observation in Great Britain in 1911, led the writer to believe that no cases of true leaf-roll or of *Fusarium* wilt have yet been proved to occur in Great Britain, but that *Verticillium* wilt is not uncommon there.

Some confusion still remains concerning the parasitism of *Verticillium albo-atrum*, inasmuch as there are many reports of its occurrence where the marked pathological effects here described were not present. Reinke and Berthold report successful inoculations, and Wollenweber obtained infections in Friedenau, Berlin, which, in the light of his later work, are to be considered as added evidence of the parasitism of this species. The result of a later successful infection experiment performed by Wollenweber with pure cultures in the Washington greenhouse is shown in Plate III. The parasitism of *Verticillium* on other plants has also been demonstrated by him and will soon be published in full. It is not to be understood that the relatively minor rôle now played by *Verticillium* as a potato parasite in the United States indicates that it is a disease that should not be feared, for, if control measures are neglected, it might easily become epidemic and as destructive as the *Fusarium* wilt.

The disease should be easily brought under control, however, by seed selection and rotation of crops. Whenever a wilted hill is observed in a field it should be taken up and both vines and tubers carried out and destroyed. When cutting seed, any with a brown stain at the stem end should be rejected. When a field is much affected by this trouble, none of the crop should be used for planting, and the ground should be given a longer rotation than usual.

LEAF-ROLL.

LITERATURE OF THE DISEASE.

No plant disease in this generation has been the subject of such general discussion as that known in Germany as the "Blattrollkrankheit," herein named "leaf-roll." None has aroused greater difference of opinion as to its nature and cause, and no other single malady of plants is to-day receiving so much investigation by skilled

pathologists as this. Possibly no disease which has appeared since the advent of *Phytophthora infestans* in the forties presents a greater menace to potato culture.

The literature on leaf-roll has become so voluminous that few will undertake to peruse all the contributions, which are, indeed, of very uneven merit, and anyone who attempts it is likely to emerge with his concepts of the disease more confused and hazy than at the start.

This bulletin is intended as a guide in the diagnosis of leaf-roll and a summary of present knowledge. It is the result in part of the writer's personal investigations, but much is owed to other writers, and particularly to Appel and Schlumberger (1911), whose critical summary of the literature on this disease is commended to all readers.

DESCRIPTION OF LEAF-ROLL.

Leaf-roll is a disease characterized by an upward rolling of the leaves, by a decreased yield of tubers, and by transmission of the diseased condition through tubers planted. Its symptoms vary so much in detail that they can be most clearly outlined by separate treatment.

The rolling of the leaves is the most constant and conspicuous symptom of this disease. The leaflets curl or roll upward on their midrib, often assuming a nearly tubular shape, and giving a plant a staring appearance (Pl. VII). This rolling is sometimes restricted to the upper leaves, while in other cases all or nearly all of the leaves on the plant exhibit it. (Pl. IV, fig. 1, and Pl. V and Pl. VIII.) This type of roll is distinct from the curly-dwarf condition described on page 37, but a very similar roll may be induced by other causes, such as wet soil, blackleg, and other diseases, as shown on page 26.

The color of the foliage changes with the advent of leaf-roll, but these color-symptoms vary greatly, from cases where the leaves assume an unhealthy, light-green color to those marked by pronounced yellowish, reddish, or purplish colors. These variations appear to depend in part upon the severity of the disease, but they are also to a large extent varietal reactions. The Peachblow, for example, develops considerable red in the upper leaves while the Pearl under the same conditions turns yellowish green. In general, early stages of leaf-roll may not be much yellowed, while more advanced cases, and particularly those in the second or third year, i. e., grown from the tubers of diseased plants, are likely to be quite yellow with reddish or purplish tints. The development of reds and purples will probably be found to take place in the different varieties according to the natural pigmentation of the sprouts and stems. The greatest variety of colors could be observed in the several numbers of the collection of seedlings which became affected by leaf-roll. Appel and Schlumberger state of this color character that, according to the

variety, it tends to be yellow-green or more reddish. With some varieties there occurs also an almost violet color, as for example, in the German sort, Hetmann. The intensity of the color varies in different years, and it appears that dry seasons bring a more intense color than moist seasons.

The time of onset is early, as compared with Fusarium wilt. The first case observed by the writer in Germany was in Giessen about June 20. Reference to the German records will show that the date when leaf-roll is first observed varies in different years. In 1907, for instance, many varieties were strongly attacked as early as June 24, while in 1909 the corresponding date in July saw less leaf-roll in their experimental plants. The date when leaf-roll appears in this country is not well fixed. Growers in the Greeley, Colo., district, where late planting is the rule, report having noticed the rolling of the leaves late in July. Leaf-roll did not develop last year (1913) in the Mitchell (Nebr.) district until about August 15, whereas the preceding outbreaks had come much earlier.

The effect on the plant is to check development. There is a lessening or cessation of growth. The shoots remain short and the leaves stand more upright.

In this respect varieties differ. The following show the stunting growth very clearly: Magnum Bonum, Hetmann, Richter's Emperor, etc., while Daber shows it but little. On such stalks the leaves, flowers, and berries are frequently smaller. For example, the berries of Hetmann on badly diseased plants in 1908 were only the size of peas, while those from healthy stalks were the size of cherries. Badly diseased plants have often no tubers or only a few. Such plants are either very weak and die early or the foliage may be comparatively well developed and remain living to the end of the vegetation period. (Appel and Schlumberger, 1911.)

The different degrees of leaf-roll are also shown in the illustrations. Plate V shows large plants with the upper leaves strongly rolled, while the plant in Pl. IV, fig. 2, is small and weak and represents the last stage of leaf-roll, having doubtless come from a tuber produced by a diseased plant. There is, however, no such shortening of stems and leaf ribs as occurs in curly-dwarf, with its resultant deformation of the plant.

The duration of life of the plant in most cases appears to be shortened by leaf-roll. This is a relative matter, since (in comparison with healthy plants) the leaf-roll cases may die earlier, as would be expected of sick plants, or they may stand until killed by frost, while (in comparison with the rapid death of American potatoes attacked by Fusarium wilt) the endurance of leaf-roll is one of the striking differences between these diseases.

The endurance of the seed piece as a character of leaf-roll is an interesting point frequently mentioned in the German literature. When Schultz [Soest] (1905) called attention to the first outbreak of leaf-roll, he laid special emphasis on the fact that the seed tubers

planted were still firm and sound at harvest time and that they were even larger in size. This observation has been verified by others, and the endurance of the seed tuber is considered by Appel and Schlumberger to be one of the symptoms of leaf-roll, though they point out that this varies greatly on different soils. They further show that the enlargement of the seed piece is not a symptom of disease, but that the same thing occurs with healthy plants. The significance of these observations relative to the endurance of the seed piece has not been made fully clear, though the discovery of Quanjer that the phloem strands in the stems of leaf-roll plants are shrunken and lignified suggests that the seed piece remains because it can not be used up by the plant. Its endurance argues against the relation of parasites to leaf-roll, since if the disease were caused by fungi or bacteria at the root, one would reasonably expect the seed piece to be decayed. The writer is unable to state whether it is the case also in the United States that the seed piece endures longer with leaf-rolled than with healthy plants. Certainly sound hills are to be found with sound seed, and many leaf-rolled plants have been dug whose seed piece had decayed. According to the writer's observation, sound mother tubers are to be found as often in the curly-dwarf disease as with leaf-roll.

The effect of leaf-roll on the tubers is strongly marked. In general, the yield is very much reduced (Pl. XIII, fig. 1) Appel (1907) states:

The growing apprehensions find their confirmations at the harvest. The diseased hills have numerous tubers very much smaller than normal, so that the yield is only about half that of a healthy field. If one uses these potatoes again for seed, the greater part fail to develop, and an uneven stand is the result. Others only germinate without sending their shoots through the earth, but branch below ground and form a considerable number of roots, so that frequently the seed tuber lies in a more or less thick tangle of roots and thin shoots. Stronger tubers succeed in growing, but the stem remains weak, the leaves are from the beginning considerably rolled, and, according to the variety, more or less colored. These colors are in this stage of all gradations from dark red to blue-red. Few or no tubers are found in such hills, so that a complete crop failure results.

Appel and Schlumberger (1911) say:

Badly diseased plants have often no tubers or only a few. When there is a setting of tubers, these are almost always very small. They are borne frequently on shortened stolons, or clustered on the underground part of the stem. This shortening of the stolons is occasionally very commonly observed, as for example, in 1908, in Eisgrub with the varieties Eduard Lefort and Long Six Weeks. This character is, however, not constant. More often hills occur where the stolons are normally developed but bear a great number of small tubers the size of hazelnuts.

A striking circumstance which must here be given special attention is that slightly diseased hills under certain conditions give an exceptionally high yield, which, however, falls rapidly in succeeding years. Such an example was afforded by the variety Modell during its cultivation in Grobzig. This sort had just come in 1907 from the breeder, and had been distributed by the German Potato-Culture Station to its experimental fields. It showed itself to be diseased on all fields, but, notwithstanding this,

gave in Groebzig a yield of 274 bushels per acre. The next year, however, the yield decreased so much (the exact record is not known) that the breeder, Gen. Oekonomierat Säuberlich, discarded it as unworthy of cultivation. To what extent such varieties not too badly diseased have their yield influenced by external conditions is shown by a comparison of the yields of this sort on the different trial grounds of the German Potato-Culture Station, which in the year 1907 were planted with the same seed from Holland. There were harvested in double centners per hectare:

No.	Trial ground.	Double centners.	No.	Trial ground.	Double centners.	No.	Trial ground.	Double centners.
1	Groebzig.....	407.8	10	Hadmersleben.....	187.2	19	Loehme.....	140.0
2	Greisitz.....	258.2	11	Scharrau.....	182.6	20	Erbesbuedesheim..	131.8
3	Calvoerde.....	245.6	12	Marienfelde.....	181.0	21	Gross-Saalau.....	130.0
4	Klein-Raudchen.....	228.7	13	Klein-Spiegel.....	180.8	22	Hohenheim.....	129.6
5	Dahlem.....	213.3	14	Schaeferhof.....	176.2	23	Singlingen.....	128.0
6	Freistatt.....	212.8	15	Siegersleben.....	164.4	24	Dolgen.....	128.2
7	Altneuhaus.....	197.6	16	Mittlau.....	154.8	25	Neckarau.....	128.0
8	Koetzig.....	192.0	17	Althoefchen.....	151.2	26	Gieshuegel.....	98.0
9	Neudorf.....	187.2	18	Ostrowitt.....	150.0	27	Altluicken.....	78.2

Of the destructive effect of leaf-roll on the potato yield, this country has altogether too good an example in the outbreak of 1911 and 1912 in Colorado. (See p. 31.)

Stem-end browning of tubers is no longer considered a reliable evidence of leaf-roll, nor is there any other character by which the disease may be detected through an inspection of the tubers. In European potatoes more or less discoloration of the vascular tissue is frequently to be found near the stem end, though this is never so conspicuous, according to the writer's observation, as the familiar stem-end browning associated with *Fusarium* wilt in the United States, except when *Verticillium albo-atrum* is present. When leaf-roll first appeared Appel commented on its striking similarity to the *Fusarium* wilt described by Smith and Swingle (1904) and wrote of the German disease:

If one cuts through the stem ends of diseased tubers, one finds that the vessels for one-half to 1 centimeter under the skin have a yellow discoloration. This discoloration is at harvest time to be seen more clearly near the stem end, but later extends until in spring it can often be traced into the eyes. Generally such tubers are less rich in starch than the healthy ones.

This discoloration was then thought to be characteristic of leaf-roll and evidence of the causal connection of a *Fusarium* with it. More extended observations threw doubt on this point, and it is now generally agreed that stem-end browning of the tubers is not an inseparable feature of the leaf-roll. Appel and Schlumberger (1911) say:

The discoloration of the vascular bundles was at first understood to be a characteristic of the leaf-roll, as announced by Appel on the basis of conditions observed in 1905 and 1906. This discoloration should consist in a partial browning of the bundles of the stem and in a yellow color of the tuber bundles, which in mild cases confines itself to the vicinity of the stem end but in severer cases extends through the entire vascular ring. Later, however, in the year 1907, when the potatoes almost everywhere

showed this appearance, the question was again investigated with an abundance of material, and it turned out that the discoloration had no connection with the disease, but that it might be produced by the weather conditions during the vegetation period. It was further proved that the discoloration is not present in the most pronounced final stages of the disease. Since the vascular discoloration is frequently associated with the appearance of mycelium, it will be taken up again in the chapter on the causes of leaf-roll. When Spieckermann states, as a characteristic symptom of leaf-roll diseased plants, that the vascular bundles are not discolored, and in particular that there is no yellow color of the vascular ring, he only means that this appearance can not be utilized as a character of the disease, for the discoloration may naturally be present in diseased plants just as in healthy ones.

HEREDITARY NATURE OF LEAF-ROLL.

The true leaf-roll is inheritable. The tubers from diseased plants produce diseased progeny as a general rule. This affords a means of distinguishing from genuine leaf-roll those temporary conditions which give rise to a similar appearance of the plants. All those who are best acquainted with the trouble agree as to the results of planting diseased seed stock, though there are different explanations therefor.

This point is one of capital importance in the control of the disease and of great interest in its bearing on the nature of the disease. It will be further discussed on another page.

CHEMICAL COMPOSITION OF LEAF-ROLL POTATOES.

It was early suggested by Sorauer that the leaf-roll potatoes exhibited a more active oxidase reaction than the healthy ones. This was determined by Grüss and later more thoroughly by Doby (1911, 1912), who proved that leaf-roll potato tubers gave a higher reaction with respect to oxidase, peroxidase, and tyrosinase; also that they had a slightly higher ash content and less starch and protein.

The full significance of these results is not yet understood. It would seem that katabolism is more rapid in the diseased plants, yet the biochemist could hardly determine by analysis which of the samples given him were healthy and which diseased.

We hope that more light will be shed on this subject through the early publication of the work of Dr. H. H. Bunzel, of the Bureau of Plant Industry, who in 1912 and again in 1913 has made a study of the leaf-roll material at Houlton, Me., using a method and apparatus designed to give more accurate results than any previously available. (Bunzel, 1912.)

NECROSIS OF PHLOEM STRANDS.

It has recently been pointed out by Quanjer (1913) that the physiological and structural viewpoint has been neglected by investigators of leaf-roll and that the small attention given has been principally devoted to the xylem, in the search for fungi, rather than to the phloem.

This author finds that the phloem strands of leaf-roll plants are shrunk and the walls thickened and lignified, resulting in such a disorganized condition that the translocation of elaborated food materials from the leaves to the tubers for storage is prevented or interfered with.

This shrinkage of the phloem strands can be detected before external signs of leaf-roll appear, but it is not present in false leaf-roll due to mechanical injury, wet soil, bacteria, overfertilizing with kainit, etc., nor in the curly-dwarf disease. It is discoverable first after the young shoot from a diseased tuber has broken through the ground and formed several leaves. Each new branch is in the beginning healthy, but the diseased condition soon manifests itself. It can be traced upward, as the plant grows, to the tips of mature diseased shoots, and even to the petioles and midribs of the leaves and to the flower stems, but not on lateral leaf veins. The same pathological condition can be traced downward in the underground portion of the stem to the mother tuber, but it rarely appears in the stolons and never in the young tubers.

This shrinkage of the phloem affords an explanation of many of the results of leaf-roll, including the thickened stems and formation of aerial tubers, which takes place when the products of photosynthesis can not be translocated. It may be connected with the "endurance of the mother tuber" and with the higher percentage of nitrogen in the latter, since these compounds can not move so freely in the shrunk phloem. The reduction of growth and the lessened yield are attributable to the same cause. The rolling of the leaves is a natural reaction of the plant to a stem injury or stoppage.

The observations of Quanjer led him to the conclusion that leaf-roll is hereditary and not parasitic and that the presence of fungous mycelium, bacteria, tyloses, and vascular discoloration are not characteristic symptoms of the disease.

It is left undetermined how this phloem shrinkage is brought about. It has not yet been produced experimentally, nor have remedial measures been found, but the need is emphasized, as pointed out by Sorauer (1913), for more experimental work, under controlled conditions, on the influence of the several natural environmental factors on the potato plant.

NONCOMMUNICABILITY OF LEAF-ROLL.

That leaf-roll is not communicable from diseased to healthy plants is the conclusion to be drawn from all available evidence. Appel, Werth, and Schlumberger (1910) report grafting a great number of diseased sprouts on healthy ones and vice versa. These were put in the greenhouse and union took place. The scions gradually died, however, after the plants were brought into the open air. During



POTATO LEAF-ROLL. TYPICAL ROLLING OF THE UPPER LEAVES OF A GERMAN VARIETY. (AFTER APPEL.)



FIG. 1.—LEAF-ROLL IN SEEDLING POTATO NO. 16518, ALEXANDER NO. 1 RED X KEEPER. WASHINGTON, D. C., AUGUST, 1912.



FIG. 2.—POTATO LEAF-ROLL, SHOWING ITS EFFECT ON TUBER FORMATION. STOLONS THICKENED AND PRODUCING NUMEROUS SMALL TUBERS ONLY. MITCHELL, NEBR., SEPTEMBER, 1911. (PHOTOGRAPHED BY FRITZ KNORR.)



FIG. 1.—POTATO LEAF-ROLL FROM COLORADO. PLANT WITH THICKENED STEMS AND AERIAL TUBERS, ALTHOUGH THE STEM IS SOUND.



FIG. 2.—POTATO LEAF-ROLL FROM COLORADO, SHOWING THE TENDENCY OF THE TUBERS TO CLUSTER AT THE BASE OF THE STEM.

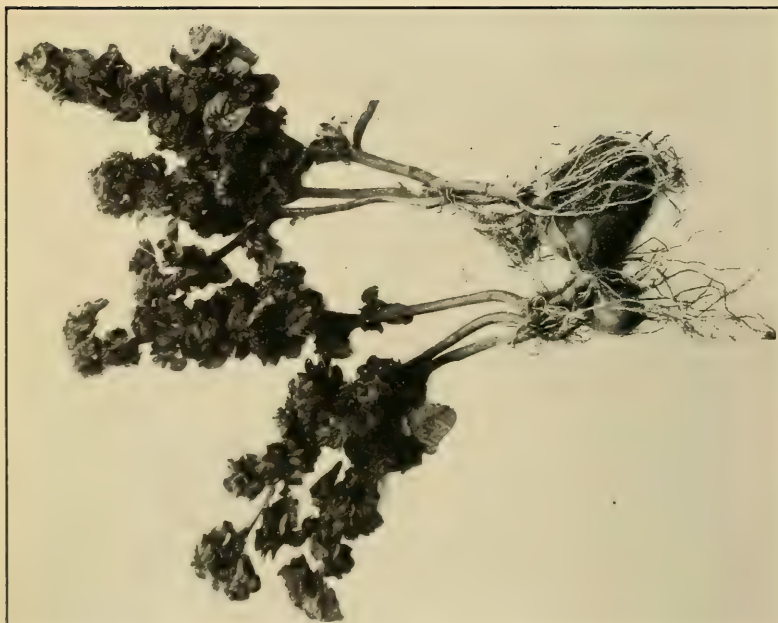


FIG. 1.—POTATO CURLY-DWARF. ADVANCED GERMAN TYPE.
(AFTER APPEL.)



FIG. 2.—POTATO CURLY-DWARF, SHOWING DWARFING,
REDUCTION OF FOLIAGE, AND ABSENCE OF TUBERS,
HOULTON, ME., AUGUST 12, 1912.

the four weeks during which they were under observation there was no apparent influence of the diseased part on the healthy. Similar experiments were performed by Schander (1912) with substantially the same results.

The evidence in the seedling collection of this bureau is also strongly negative. Certain varieties with clearly marked leaf-roll have stood surrounded by healthy varieties without any indication of the spread of the disease.

RELATION OF FUNGI TO LEAF-ROLL.

The first investigations of leaf-roll made by Appel in 1905 led him to believe that it was due to a *Fusarium* similar to that described by Smith and Swingle. Mycelium was found in the vascular bundles of diseased plants, and cultures were derived from the stem ends of tubers. The species of *Fusarium* was not determined with certainty, for at that time the identification of *Fusaria* by morphological characters was not possible. The findings of Appel were verified by many other workers, and for a time leaf-roll was generally attributed to a *Fusarium*. Some good authorities are even now strongly inclined to this theory (Köck and Kornauth, 1912).

It has, however, been abundantly proved that in many cases of leaf-roll no fungus is present, and that these include the most advanced stages of the disease. The theory has been advanced by Appel that these fungus-free cases represent the second stage of a disease, the first stage having been due to *Fusarium* infection, and the weakness caused by the fungus transmitted to the progeny. This hypothesis has not been supported by the observed facts. It is greatly weakened by the results of the writer's seedling studies, which show the earliest typical stages of leaf-roll to be fungus free and by the fact that no inheritable leaf-roll follows *Fusarium oxysporum* infections in America. The subject has been somewhat obscured by the mass of polemic discussion, but it is now quite generally admitted that the presence of fungous mycelium is not a characteristic of leaf-roll.

The number of cases in Europe where mycelium has been found in diseased plants is so great that some explanation is required. In the opinion of the writer, the *Fusaria* that have been found in connection with leaf-roll in Europe are of nonparasitic types which have invaded diseased or weakened tissues. Where mycelium is reported in the bundles, and especially where it is found up to the tips of the stems, the first inference must be *Verticillium albo-atrum*, whose hyphæ, though thinner, may easily be mistaken for that of *Fusarium*. Mixed infection with *Verticillium* may account for most of the present confusion. This fungus is widespread in Europe, while it is now quite definitely established by Dr. Wollenweber that the *Fusarium*

oxysporum of Smith and Swingle is different from any European species yet known.

Leaf-roll diseased plants in America have been free from fungous infection in so far as the writer's observation goes, except for certain cases in Colorado, which were plainly mixed infections with *Fusarium oxysporum*, and here many other plants in the same field were fungus free. The external appearance of leaf-roll and wilt present many differences already given in detail.

Other fungi than *Fusarium* have also been reported in connection with leaf-roll, but for the most part without verification, e. g., *Solanella rosea* (Vanha, 1910), Phoma, Bacteria, etc. (Stoermer, 1910). The burden of proof is now on those who attribute leaf-roll to fungi to identify their organism through pure culture and reproduce the disease by inoculation. For a more extended summary of this phase of the subject, see Krause (1912).

LEAF SPOTTING IN RELATION TO LEAF-ROLL.

The occurrence of spots or flecks on potato leaves is not an invariable symptom of leaf-roll, but is often observed in connection with it, particularly in the severer types of leaf-roll. The spots observed by the writer were small, dark-brown flecks in the tissues of the terminal leaves, generally between the veins. They have also been found on plants not attacked by leaf-roll. These spots are apparently free from fungi and are believed to be due to physiological causes. Frank (1897) connected these spots with several types of what he termed "Kräuselkrankheit," but Appel is undoubtedly correct in pointing out that there is no connection between the spots and the curly-dwarf or the leaf-roll.

OTHER LEAF-ROLLS.

Typical leaf-roll must be differentiated from several similar appearances, due to other causes, as follows:

(a) Temporary leaf-roll due to water-logged soil. There are not infrequent cases in poorly drained land or in seasons of excessive precipitation when the potato plants suffering from lack of soil aeration show this by a rolling of the leaves. This can, however, be distinguished from the true leaf-roll, as the symptom disappears when the cause is removed, while true leaf-roll is inherited. The plants, moreover, do not undergo the same color changes. (Appel and Schlumberger, 1911.)

(b) A leaf-roll condition, usually of temporary duration, may be induced by heat or drought, or by the use of excessive quantities of fertilizer, especially potash (Quarjer, 1913). In such cases the rolling may be more marked on the lower leaves.

(c) Blackleg (*Bacillus phytophthorus*) produces an upward rolling of the leaves, with a yellow color. The later stages of this disease may at first glance exactly simulate leaf-roll, but as blackleg is invariably associated with a blackening and shriveling of the base of the stem the two can not be confused after the plants in question have been pulled up.

(d) Curly-dwarf is perhaps an allied malady, but differs in that there is a pronounced shortening of the stem and branches, a crinkling or downward curling of

the leaves, and normal color and turgidity. This is further described and illustrated on page 37.

(e) Wilt of both the *Fusarium* and *Verticillium* types may at certain stages bear a slight outward resemblance to leaf-roll, but they are distinguishable by the occurrence of the causal fungi, by the discoloration of the wood vessels of the lower stem, and by the brown stain in the stem end of the tubers. These wilts cause the rapid death of the plants attacked, or at the least an abnormally early maturity, while leaf-roll plants live nearly as long as healthy ones.

(f) *Rhizoctonia* stem-blight, as it occurs in Colorado and other Western States, may in one stage be easily confused at first sight with leaf-roll. (See under "Rosette," p. 40.) The leaf-roll symptom may, in fact, be induced by stem injuries of various kinds, but the disturbance is fundamentally different from true leaf-roll in that it is not transmissible. Heribert-Nilsson (1913) has described such a leaf-roll, due to hypocotyl injury by an insect, *Agrotis segetum*.

In Germany, leaf-roll was formerly included under the collective term "Kräuselkrankheit," which is now being restricted to curly-dwarf. Appel also separates a "bacterial ring disease," which has not yet been thoroughly worked out, and which can not at present be identified with any American malady. (Appel and Kreitz, 1907.) A new disease, to be described as "streak," also enters to some extent into the complex situation in America.

There is little likelihood of confusion with tip-burn, as this disease is already so well known. The illustration, Plate XIV, shows the characteristic browning and curling of the margins of the leaflets due to excessive transpiration during hot, dry weather. Tip-burn is comparatively much less prevalent in the cooler climate of Europe than in the United States, but it was observed by the writer in typical form in Dresden during the hot, dry summer of 1911.

LEAF-ROLL IN EUROPE.

The leaf-roll disease of potatoes first came into public notice in Europe in 1905, when a small epidemic occurred in Westphalia and other points in Germany. Appel found it in the same year in Denmark. It is his opinion that it had also prevailed many years before but had been forgotten or confused with other troubles under the collective term "Kräuselkrankheit." In 1907 a more general outbreak occurred in Germany, and much alarm was expressed (Arnim-Schlagenthin, 1908). The disease was reported on all sides. In Austria the Government appointed a special commission to investigate the disease. The experiments thus begun are still in progress. Up to date four reports have been published: (1) Dafert, 1911; (2) Köck and Kornauth, 1911; (3) Reitmair, 1912; (4) Köck and Kornauth, 1912. In these the reader will find recorded many data which are only briefly mentioned here.

Among other investigations begun then or a little later, and in addition to those of Appel and his assistants at the Kaiserliche Biologische Anstalt für Land- und Forstwirtschaft at Dahlem, Berlin,

from whom so much has already been drawn, the ones deserving of special mention are those of Dr. Schander, in the Kaiser Wilhelms Institut für Landwirtschaft in Bromberg and of Dr. Spieckermann in Muenster. So many others have written on this subject that it is possible only to refer to the extensive bibliographies of Appel and Schlumberger, 1911, of Köck and Kornauth, 1911 and 1912 (*Mitteilungen des Komitees zum Studium der Blattrollkrankheit*, Nos. 2 and 5), and of Himmelbaur, 1912.

GEOGRAPHIC DISTRIBUTION OF LEAF-ROLL.

Much is lacking in the knowledge of the exact distribution of the leaf-roll diseases, but it begins to appear that it is now, or soon will be, a factor in potato culture wherever this crop is grown. Its occurrence is certain in Germany, Austria-Hungary, Switzerland, the Netherlands, Denmark, and Sweden, as well as in the United States. It is probably in Norway, Russia, Bulgaria, and Roumania. That it has not been reported in France, Belgium, and England may be because of lack of sufficient observation. The somewhat limited observations of the writer in these countries in 1911 failed to disclose any true leaf-roll. The disease reported under that name from Ireland is the *Verticillium* wilt.

In Germany the leaf-roll has been most widespread and injurious in the west, e. g., in Westphalia and the Rhine provinces, though since its first outbreak in 1905 the introduction of healthy seed stock from other districts is reported to have restricted its spread. Leaf-roll has been observed in nearly all parts of Germany, but in most cases only scattered fields suffered.

In Austria, also, the disease seems to be present in nearly all districts, including Hungary, though not always to a destructive degree.

OCCURRENCE OF LEAF-ROLL IN THE UNITED STATES.

Two developments of leaf-roll in this country have been studied by the writer. One was in a collection of seedlings grown by Prof. William Stuart, of the Bureau of Plant Industry, and the other was a destructive outbreak in eastern Colorado and western Nebraska during 1911 and 1912. The leaf-roll in the seedling collection, while not of direct economic importance, afforded an opportunity to diagnose the trouble and differentiate it from others and also suggested a probable solution of the problem of control.

The western outbreak was, on the other hand, the cause of immense losses and brought the leaf-roll problem, for the first time, to the forefront in this country. That it will continue to be an important economic factor in American potato production is indicated by its discovery in two new localities in 1913. The writer found a field of Irish Cobbler near Onley, Va., with well-marked leaf-roll characterized by rolled leaves with a reddish tinge and stunted growth. The

source of this seed was thought to be Maine. Dr. I. E. Melhus found another field in northern Maine with 100 per cent leaf-roll, a noteworthy occurrence when the extremely vigorous and healthy condition of the potatoes in that district is considered.

As stress will be laid, later in this bulletin, on the development of leaf-roll in seedling varieties, in connection with the problem of controlling this disease, it will be well to describe the collection which formed the basis of the writer's studies.

HISTORY OF THE SEEDLING COLLECTION.

In 1904 Prof. L. R. Jones, then botanist of the Vermont experiment station, was sent to Europe by the Bureau of Plant Industry to search for potato varieties resistant to late-blight, *Phytophthora infestans*. He brought back about 100 varieties, which were placed on trial at several points, including the Vermont experiment station at Burlington, where Prof. Stuart began crossing the European sorts with each other and with American varieties. Notable success was achieved in 1909 in securing seed from a large number of crosses; about 25,000 seedlings were raised the following season, propagated that year in Washington, the following year in New York, and in 1912 in both New York and Maine.

It had been observed by Prof. Stuart that some of his seedling varieties from earlier crosses exhibited sudden loss of vigor. Occasional numbers which had in the beginning showed promise would produce only weak or abnormal progeny.

DISEASE PHENOMENA IN THE SEEDLINGS.

Such was the condition found by the writer in the breeding fields in Maine and New York in 1912. These fields consisted of 10 and 16 acres, respectively, and contained over 10,000 seedlings of known parentage, 5 hills of each sort.

As might be expected, these seedling potatoes showed every degree of variation in plant characters, color and size of leaves, habit of growth, etc., but in addition many showed distinct evidence of a diseased condition, and indeed of quite distinct types of disease, which are herein described as leaf-roll, curly-dwarf, and "streak."

It is noteworthy that in neither field was there any trace of Fusarium wilt, nor of Verticillium wilt, blackleg, or mosaic disease, although the latter three were common in adjoining fields. This is a very important fact, since it strongly supports the argument that these are distinct diseases. The reason for the nonoccurrence of these troubles is that the seedling varieties, since their origin from seed, had been grown from selected tubers, and no stronger proof is needed that such diseases may be controlled in commercial seed growing by the tuber-unit selection method, applied, if need be, to a seed plat of limited area, from which the main crop is propagated.

The sharp differentiation between healthy and diseased varieties in adjacent rows, and other field evidence, indicates that the leaf-roll and curly-dwarf are manifestations of physiological weakness and associated with decline or loss of vigor of the strain. That certain varieties show a greater tendency to such degeneration phenomena is evident, and the still more marked development of these troubles on certain seedlings emphasizes their relation to the varietal problem. That many other seedlings in the same field exhibited unusual health and vigor seems convincing evidence that in this seed selection and breeding the way lies open for the complete solution of this problem of leaf-roll control.

Of 59 of these diseased seedlings selected at random as typical examples in 1912, 29 were affected with leaf-roll and 30 with curly-dwarf; and of 22 selected in 1913, 7 had leaf-roll and 15 had curly-dwarf. The parentage of these is indicated in Table I, for its bearing on the question that will be asked as to whether certain combinations of varieties have a tendency to produce leaf-rolled or curly-dwarfed offspring.

TABLE I.—*Parentage of diseased seedlings.*

Parent varieties.	Number diseased with—		Parent varieties.	Number diseased with—	
	Leaf-roll.	Curly-dwarf.		Leaf-roll.	Curly-dwarf.
Geheimrat Theil × Keeper.....	2	2	Apollo × Silverskin.....	1	.....
Sophie × Keeper.....	11	3	Gem of Arrostook × Round Pink-eye.....	1	5
President Krüger × Keeper.....	1	1	Daisy × Keeper.....	.....	1
Delaware × Keeper.....	.....	2	Early Eureka × Keeper.....	.....	1
Norcross × Keeper.....	1	.....	Holborn Abundance × Irish Seedling.....	3	5
Gem of Arrostook × Keeper.....	7	4	Alexander's No. 1 Red × Irene.....	.....	3
Alexander's No. 1 Red × Keeper.....	1	4	Manly × Irene.....	3	.....
Round Pinkeye × Keeper.....	.....	2	Garnet Chili × Silverskin.....	.....	2
Irish Cobbler × Keeper.....	.....	1	Irish Cobbler × Irish Seedling.....	.....	1
Green Mountain × Keeper.....	.....	2	Apollo × Irish Seedling.....	.....	1
Keeper × Round Pinkeye.....	.....	1			
Keeper × Silverskin.....	.....	3			
Sophie × Irish Seedling.....	4	.....			
Delaware × Round Pinkeye.....	1	1	Total.....	36	45

A much more detailed analysis of the characteristics of these varieties and their seedlings is really required to answer this question. It is clear, however, that some varieties, like Keeper, are poor parents. A large number of successful crosses with Keeper were secured by Prof. Stuart because it produced an abundance of pollen, but the offspring of these have been so unsatisfactory on account of their tendency to curly-dwarf and leaf-roll that the variety will not be used again for crossing.

From different crosses having the same varieties as parents there have come seedlings, some of which were leaf-rolled and some curly-dwarfed. No. 16472, illustrated in Plate IV, figure 1, is a perfect type of leaf-roll in a cross between Alexander's No. 1 Red and Keeper, while No. 16503, shown in Plate XI, figure 1, is an equally

good type of curly-dwarf in another cross between the same parents. No cases are recorded where both leaf-roll and curly-dwarf were found in the same seedling number, but there are several instances where diseased and healthy plants occur in the same row. The results of 1913 are more striking in their proof of the hereditary nature of leaf-roll and curly-dwarf. This field contained 20 hills of each variety, planted with 10 tubers, each cut in half, and the two halves of each seed potato dropped in adjoining hills. As a general rule, all the 20 hills were uniformly diseased, as shown in Plate VI, illustrating No. 2171, one of the best types of leaf-roll in the collection. Two plants from this row are shown in a closer view in Plate V. Compare also Plate XII, showing the uniform affection by curly-dwarf of Nos. 821 and 822, which are hybrids between Sophie and Keeper.

In several cases in 1913 only a portion of a variety was affected, but with few exceptions the two hills originating from one tuber behaved alike. Row No. 1763, for instance, had two hills with leaf-roll, then four normal, then two leaf-rolled. Row No. 1613 had the first pair of hills normal, the second and third leaf-rolled, the fourth and fifth pairs normal, and all the remainder leaf-rolled. Other examples of similar inheritance of curly-dwarf are cited on page 38.

WESTERN OUTBREAK OF LEAF-ROLL.

For many years there has been an important center for potato production in Weld County in northern Colorado, known as the Greeley district. More recently a considerable acreage of potatoes has been grown on the North Platte River in western Nebraska.

Since the average rainfall at Greeley is not large, all potatoes must be grown under irrigation. The potatoes generally receive sufficient rain in the spring to keep them growing until July, when irrigation is begun and repeated as needed. Rotations of crops have been generally practiced. A common one is, alfalfa two or three years, potatoes, beets, and grain. The methods of culture have been considered good, and large yields were secured for years. It has been estimated that 35,000 to 40,000 acres are annually planted to potatoes in the Greeley district. The total yield per year was stated by Bennett (1907) to be 9,000 to 14,000 carloads, or 4,000,000 to 6,000,000 bushels. This crop has been the greatest factor in promoting the prosperity of this section. The leading varieties have been Pearl, Rural New Yorker, and Early Ohio.

Some difficulties had been experienced from diseases of potatoes previous to 1910. The greatest stress had been laid on the *Rhizoctonia* stem-blight, a trouble which assumes a peculiar form in this western country. (See under "Rosette," p. 40.) Potato culture has been, in fact, restricted to the lighter soils, the physical condition of

which is further improved by plowing under alfalfa just before planting potatoes, and by the practice of extremely deep cultivation with special implements.

Scab of the tubers has not been uncommon, and in some seasons there has been a late summer occurrence of early blight, but the most important disease has been perhaps the Fusarium wilt (*Fusarium oxysporum*). This fungus was widely prevalent throughout the district, and its effect on the crop could be observed with especial clearness in fields where potatoes had been grown for two or three consecutive years. Stem-end browning is common in Greeley potatoes, but the loss from Fusarium dry-rot has not been large. Crop rotation kept the loss from wilt down to a point where the disease caused little concern, though it is possible that a longer rotation would have been better.

These details concerning the prevalence in Colorado of *Rhizoctonia* and *Fusarium* have been given at this point because they were at first charged with the losses due to leaf-roll.

During the season of 1911 there was an outbreak of a potato disease which practically destroyed the crop in northern Colorado and western Nebraska. The shipments from the Greeley district fell from an expected 7,000 to 200 cars. The average yield of the 3,190 acres in the Mitchell (Nebr.) district was only 14 bushels per acre that year, as compared with 103 in 1909, 39 in 1910, and 102 in 1912. The cause of this extraordinary falling off in yield was the leaf-roll disease, though it was at first locally thought to be *Fusarium* and *Rhizoctonia* combined with the effect of the very dry and unfavorable weather of spring and early summer. It was predicted that with normal weather conditions and some improvements in cultural practices the disease would not be likely to recur (Corbett, 1912). In 1912, however, very favorable conditions for growing crops prevailed. There was an abundance of moisture in the soil in the spring and favorable temperatures throughout the season. Nevertheless, the disease again prevailed, nearly as severely as before. The shipments from Greeley were about 700 cars, with half the normal acreage. The Scottsbluff section came through with better results; for, although the leaf-roll appeared in June and threatened a repetition of the 1911 experience, there was a revival of the crop, after some midsummer rains, and a fair yield.

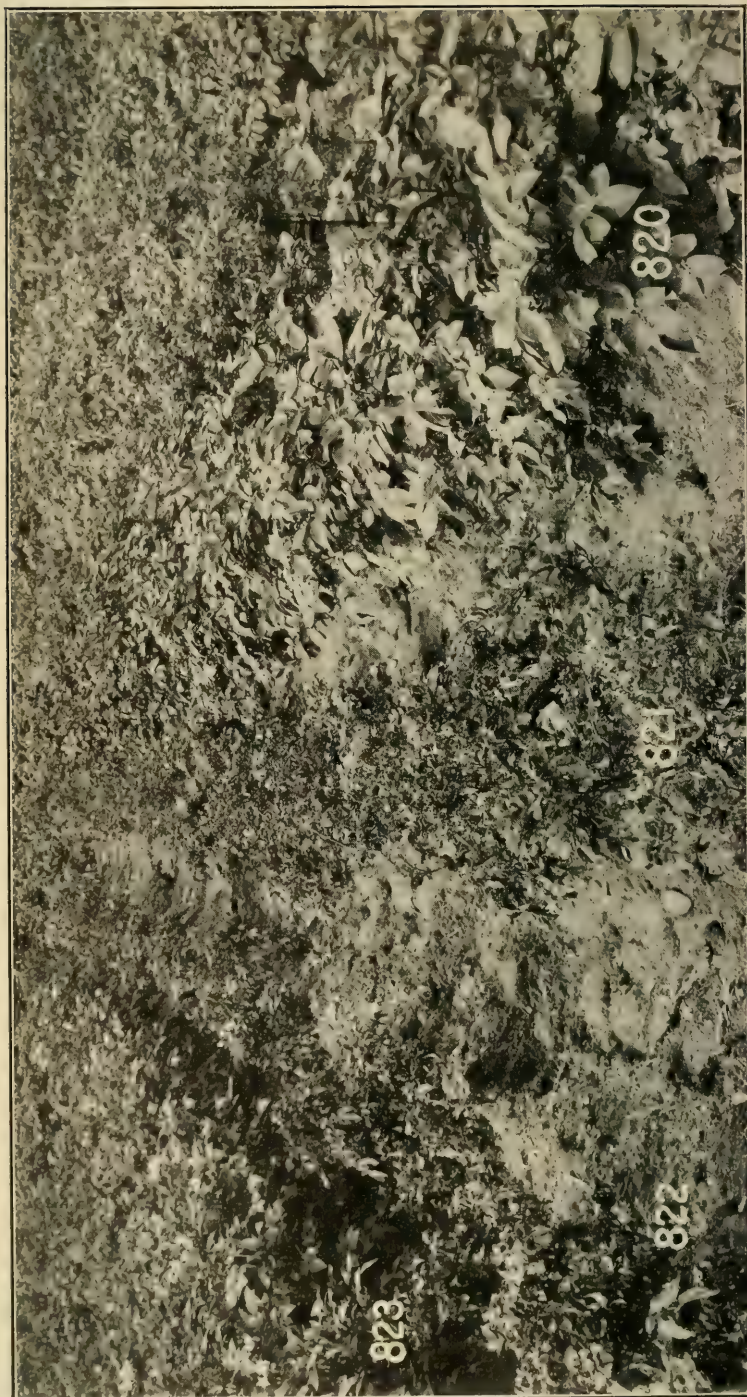
It now seems indisputable that the Colorado and Nebraska disease is the same type of leaf-roll observed in the Maine and New York seedlings and that this is the trouble called "Blattrollkrankheit" by the Germans. There have been variations in the symptoms observed, but it appears that this is also the case in different parts of Germany or between different varieties there. The American trouble exhibits the rolling, the yellow color, and all the important characters de-



FIG. 1.—POTATO CURLY-DWARF. A DISEASED AND A HEALTHY PLANT OF THE SAME VARIETY, SEEDLING NO. 16503, ALEXANDER NO. 1 RED X KEEPER. HOULTON, ME., 1912.



FIG. 2.—POTATO CURLY-DWARF. AN ADVANCED CASE BETWEEN TWO NEARLY NORMAL HILLS. NO. 13372, HOLBORN ABUNDANCE X IRISH SEEDLING. COMPARE PLATE XIII, FIGURE 1, WHICH SHOWS THE YIELD FROM THESE HILLS. HOULTON, ME., 1913.



POTATO CURLY-DWARF, SHOWING ITS TRANSMISSION THROUGH SEED TUBERS AND VARIETAL SUSCEPTIBILITY AND RESISTANCE IN SOPHIE X KEEPER HYBRIDS NOS. 821 AND 822 (IN THE CENTER), ALL DISEASED, AND NOS. 820 AND 823 (ON THE RIGHT AND LEFT, RESPECTIVELY), UNIFORMLY HEALTHY. HOULTON, ME., AUGUST, 1912.

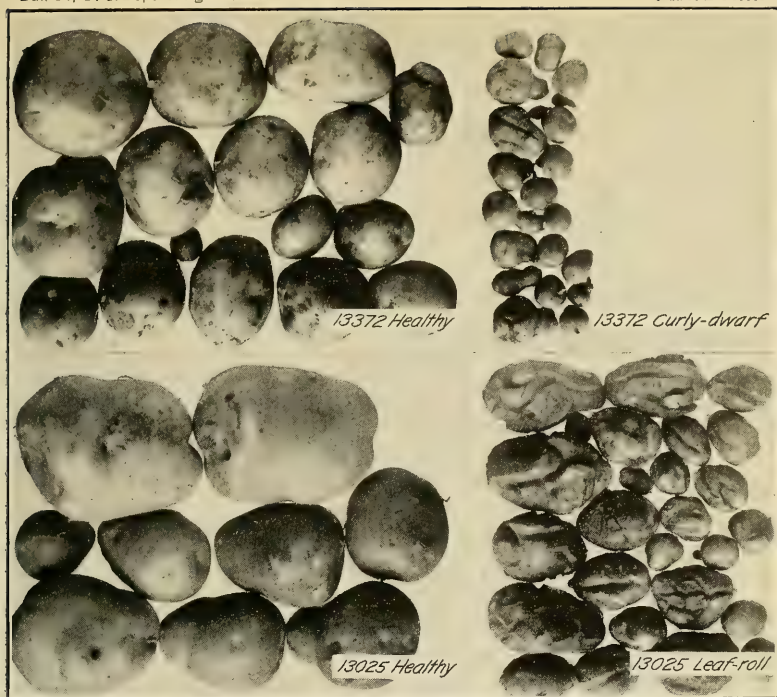
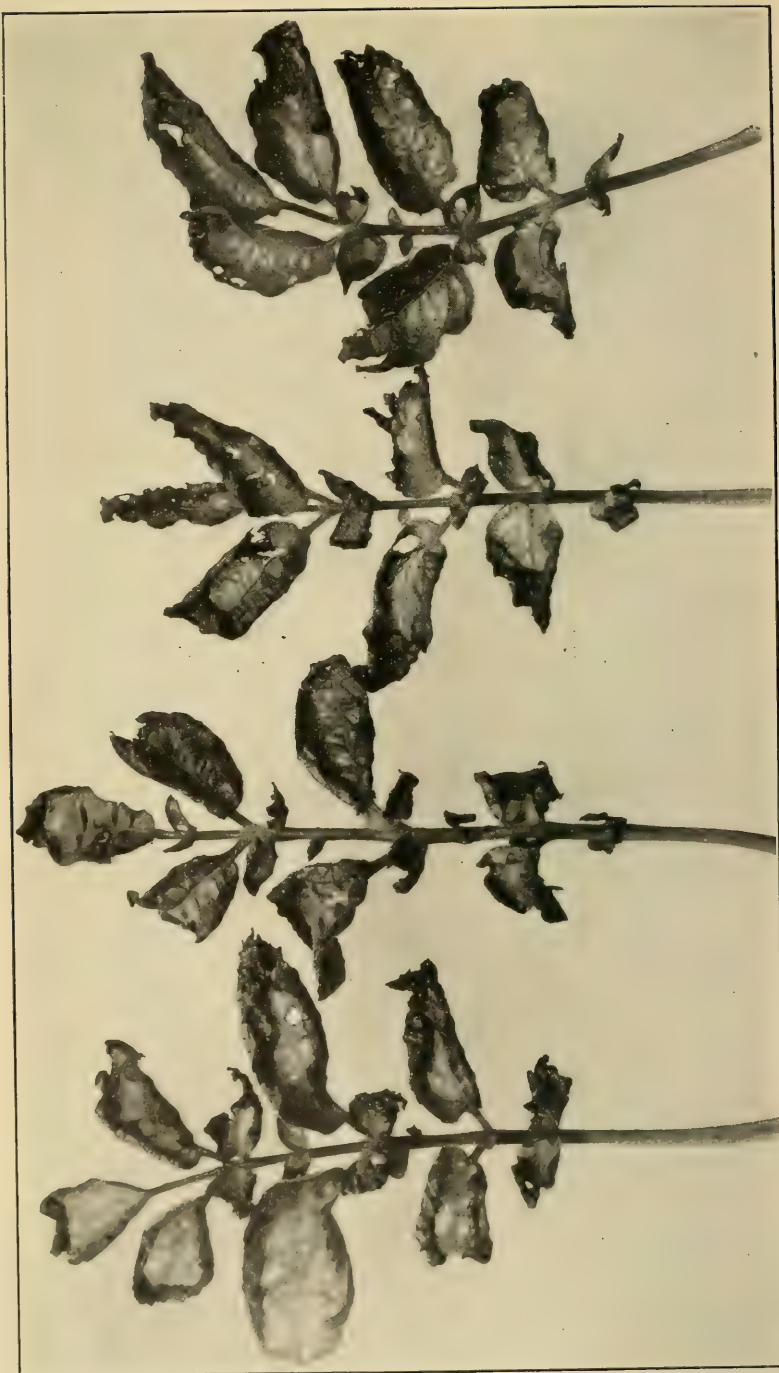


FIG. 1.—POTATO LEAF-ROLL (BELOW) AND CURLY-DWARF (ABOVE), SHOWING THE YIELD OF HEALTHY AND DISEASED HILLS OF THE SAME VARIETY. HOULTON, ME., SEPTEMBER, 1913.



FIG. 2.—POTATO CURLY-DWARF. COMPARISON OF THE YIELD OF HEALTHY AND DISEASED HILLS OF THE SAME VARIETIES. HOULTON, ME., SEPTEMBER, 1913.



POTATO TIP-BURN, A HOT-WEATHER REACTION OF POTATOES GROWN IN MIDSUMMER AT WASHINGTON, D. C., (FOR COMPARISON WITH LEAF-ROLL.)

scribed, and the effect on the plant is the same, though possibly in the western cases there have been more pronounced abnormalities in stolon and tuber formation than are described in the German literature. These effects are illustrated in Plate VIII, figure 2, and Plate IX, figure 2, which show the numerous stolons, often thick and white, bearing many small tubers, frequently strung along like beads. The few tubers which attain any size are generally clustered around the base of the stem, as in Plate IX, figure 2. This clustering is characteristic of leaf-roll. Kornauth and Reitmair (1909) say: "The stolons are greatly shortened. Many times the tubers are attached directly to the stem."

AERIAL TUBERS.

Aerial tubers are very frequent, and there is often a thickening of the upper stem and leaf petioles which seems to be another result of the plant's efforts to store starch above ground. (Pl. IX, fig. 1.) This is a distinct phenomenon from the formation of aerial tubers due to lesions on the stem caused by *Rhizoctonia*, for the leaf-roll cases show no trace of fungous injury. Neither of these characters is constant, however. Mr. Fritz Knorr informs us that "in 1911 the greater percentage of the plants took on this stoloniferous character and a smaller portion developed the aerial tubers; this year (1912) the reverse was the case. We had but few of the stoloniferous plants and very many of the aerial tubers."

These are reactions of the plant to the abnormal physiological conditions accompanying the leaf-roll, which are in turn influenced more or less by moisture and food supply and by weather factors. It is easy to understand how aerial tubers are produced by the fungus *Rhizoctonia*, which causes lesions on the stem near the soil line and thus prevents the translocation of starch from leaves to tubers, for we can produce the same result by a mechanical injury, i. e., "girdling" the stem or by rooting a cutting from a potato shoot in such a manner that no node is covered by soil and stolons can not, in consequence, be formed.

In those leaf-roll diseased plants which form aerial tubers there are no below-ground fungus lesions, and some other force, such as the phloem shrinkage described by Quanjer, must be acting to hinder the storing of starch in the tubers.

There is evidence, as mentioned in the paragraph on the relation of enzymes to leaf-roll, which suggests that there may be unusual katabolic activities going on in the diseased plants, which would consume the carbohydrates formed in photosynthesis, leaving little or none to be laid by in the tubers during the period of leaf-roll prevalence. If, at a later date, under the influence of favorable weather, for example, an excess of starch was again formed in the

leaves, but some physiological defect prevented its prompt translocation to the below-ground tubers, it would be laid up in thickened branches and aerial tubers.

An interesting and important line of study in pathological physiology presents itself in the determination of the ways in which leaf-roll potatoes differ from healthy ones. Doubtless a better knowledge of the nature of leaf-roll will lead to a determination of its cause. Up to the present but little more has been done than to diagnose leaf-roll more accurately and separate it from other maladies with which it has been confused.

CAUSE OF LEAF-ROLL.

The hypotheses as to the cause of leaf-roll are numerous but exceedingly varied. They have indeed only one point in common—that all are as yet unproved. It has been argued by one that leaf-roll results from the use of unripe tubers for seed; by another, that it is due to the employment of matured tubers for seed; while a third believes that seed from prematurely ripened plants is a cause of leaf-roll. The disease is attributed by some to a lack of mineral elements in the soil, while others advance evidence that it is caused or aggravated by an oversupply of these same mineral elements. Poor cultural methods, lack of seed selection, and varietal degeneration are other suggested causes. The struggle between those who believe leaf-roll due to fungi and those who think it nonparasitic is nearly fought out, with the victory apparently in sight for the latter. Many signs now point to the plant breeder as the one who will finally triumph over this malady.

The present-day opinions on the cause of leaf-roll may be briefly reviewed. (Appel and Schlumberger, 1911.)

The relation of fungi to leaf-roll has already been briefly summarized. Much more on this point will be found in the writings of Himmelbaur, of Köck and Kornauth, and of Appel and Schlumberger. (See "Bibliography," pp. 44-48.)

On the question of using mature or immature seed, Hiltner (1905) is the leading advocate of the stand that the immature seed stock gives an abnormal growth. On later evidence, he limits this to those potatoes which are prematurely ripened by drought or other untoward circumstances. Against this is to be balanced the very extensive use, with good results, of immature tubers for planting. In Scotland, particularly, this is held to be the best practice. Hiltner (Appel and Schlumberger, 1911) further holds leaf-roll to be the result of excessive applications of fertilizer of unbalanced composition at the wrong time. He considers that the concentrated salts, especially potash salts, enter the roots and cause a disturbance in nutrition. Through the presence of these salts in the vessels, the water in them is prevented from rising. He thinks that these salts also favor the

entrance of fungi into the vessels. In this connection it may be noted that no fertilizers are used in Colorado, but that, according to Headden (1910), an abnormally large amount of nitrogen is present in these soils.

Experimental evidence on the effect of fertilizers is brought forward by Osterspek (Appel and Schlumberger, 1911), who comes to the following conclusions:

- (1) The leaf-roll occurred most severely where no fertilizer was used.
- (2) The second degree of severity was where the potash salts were left out.
- (3) The absence of phosphoric acid favored the leaf-roll to a lesser degree, though still perceptibly.
- (4) The use of a complete fertilizer, with nitrate of soda, superphosphate, and potash salts, tends to reduce the prevalence of leaf-roll.
- (5) A second application of nitrate of soda after stable manure or after a complete commercial fertilizer reduced the leaf-roll.

Many practical growers have attributed leaf-roll to defective cultural conditions, poor soil, etc. Störmer (1911) also subscribes to this view: "Through such means as the selection of the smallest potatoes for seed stock, poor preparation of the soil, excessive applications of commercial fertilizers, heating of the potatoes in the silo, etc., a degeneration of the stock may be brought about and with this the leaf-roll." However, he has not yet exact proof of this. He believes that a hereditary leaf-roll may be caused by soil influence, "that one and the same potato may degenerate or remain healthy, according to the place where grown." He reports having succeeded in bringing up the vigor of a weak stock by growing it in one year on a poor, sandy soil. This leads us to the consideration of the problem from the varietal viewpoint.

VARIETAL SUSCEPTIBILITY AND RESISTANCE TO LEAF-ROLL.

The first appearance of leaf-roll in Germany was on the variety *Magnum Bonum* and was considered as an evidence of varietal deterioration (Schultz [Soest], 1905). *Magnum Bonum* is one of the older varieties. It has also been one of the most popular and, since its introduction from England, has become one of the most widely cultivated potatoes in Germany and Austria. It has everywhere proved the most susceptible to leaf-roll, but those who take this to be proof of the general "running out" of the variety have to meet several counter arguments. Healthy stocks of *Magnum Bonum* are still to be found. The leaf-roll attacks many other varieties, and it occurs even on plants grown from seed.

As to the relative susceptibility or resistance of American varieties there are almost no data. The Pearl, in the West, seems more liable to the trouble and may have to give way, like the *Magnum Bonum*. In Germany, however, extensive records are already kept by the German Potato-Culture Station (Von Eckenbrecher, 1912) and others.

It is not thought worth while to reproduce here the tables and summaries of these variety tests. The varieties grown in Europe are almost entirely different from those grown in the United States, and repeated experiences have shown that few of them will thrive here if introduced. In general, the indications are that varietal differences in susceptibility to leaf-roll do exist, but that the tests need to be carried on longer before any conclusions are drawn respecting given varieties. It seems certain that leaf-roll is not a result of "running out" of varieties through old age, for many quite recently originated strains are affected. More striking still is its occurrence in seedlings, which has been observed by several workers.

There have been unusual opportunities to study the occurrence of leaf-roll in the Stuart collection of 10,000 seedlings, where perhaps the most striking feature was that the leaf-roll was confined to certain numbers. The five hills of a kind would be uniformly affected, while those on either side were perfectly healthy. Clearly, the disease is not due entirely to soil or climatic influences, and certainly there was no indication of fungous infection. The marked contrast between diseased and healthy rows is well shown in Plate VI, in which the left-hand row is a hybrid (No. 2171) between Sophie and Keeper, the healthy row on the right being from the same cross (No. 2165).

An interesting suggestion is put forward by Hedlund (1910), that leaf-roll is a pathological, adaptative mutation, and, further, that since acquired characters are not inherited the leaf-roll character must be latent in normal potatoes.

CONTROL OF LEAF-ROLL.

No measure offers more hope of success in controlling leaf-roll than the use of better seed stocks. Three means may be used to bring this about: First and simplest, the importation of seed potatoes from districts where the disease is unknown. This affords relief but may not greatly raise the standard of quality. Second, hill selection, to pick out from weak varieties strains that will withstand the disease. This has been done already by Von Lochow (1910), who took several types from the variety Professor Wohltmann and bred them in pure lines. The result was that certain of these pure strains showed susceptibility to leaf-roll, while others remained entirely or nearly free from it. Third, new varieties may be bred from seed. This, while requiring the most time, may be the best means for meeting the requirements where whole districts are attacked, as in the Colorado outbreak. That such good varieties can be produced one can hardly doubt after seeing the departmental collection of over 10,000 seedlings with its infinite variety of disease-resistant qualities.

It is the prevailing opinion of European investigators that leaf-roll is inherited—i. e., that the tubers from diseased hills will produce diseased progeny. Cases are cited where the first crop after the

appearance of the disease was normal, but later harvests fell to nothing. No reliable results are available in this country. Conflicting reports come from farmers in the Greeley section; but, as no pathologist accustomed to the diagnosis of leaf-roll saw either crop, the relative amount of disease in home-grown and outside seed remains unknown.

It seems a wise precaution to use only selected seed from such sources as Minnesota and Wisconsin for planting next year where leaf-roll occurred last season. It may be that the disease will not appear on crops from home seed, but the chances are that it will.

The introduction of new and more vigorous varieties affords a still more hopeful means of ultimately controlling the situation. The problem of finding the best source of seed is the most important one now confronting potato growers in the region affected by these troubles. What is needed are selected stocks, true to name, with vigor unimpaired and free from disease. The present difficulty is that it is almost impossible to find such potatoes in large quantities. Where growers have made experiments with outside seed they have, as a rule, made their purchases in the open market or from middlemen who have filled their orders with uninspected stocks, for which reason no conclusions can be drawn from any experiments to date.

There is fortunately a movement to organize among potato growers in the principal Northern States, and this is backed by their State experiment stations in a way that should in time make a supply of reliable seed available.

It would be well to follow the example of Germany, where a system of official inspection is being inaugurated, through which growers and purchasers may be assured that the crop from a given estate is free from leaf-roll. Such a certificate can be granted only after an inspection of the growing crop. The importance of such an inspection in midsummer by a representative of the purchaser or by an official expert can not be overstated. It is entirely impossible to determine the vigor and freedom from leaf-roll of a stock of potatoes after harvest.

The practical phases of such a system of seed inspection and certification will be discussed more fully in a later publication.

CURLY-DWARF.

Under the name "curly-dwarf" there is to be differentiated from the leaf-roll a peculiar disorder, characterized by a dwarfed development of the potato plant, accompanied by a pronounced curling and wrinkling of the foliage, which has been compared to Scotch kale and Savoy cabbage. It is known in Germany as "Kräuselkrankheit." The accompanying illustrations from photographs (Pls. X and XI) show the typical appearance of this disease more clearly than the printed description.

The stem and its branches, the leaf petioles, and even the midribs and veins of the leaves all tend to be shortened in many cases to a very marked extent, and particularly in the upper nodes of the plant, so that the foliage is thickly clustered. The diminished growth of the leaf veins, in proportion to the parenchyma, results in a bullate, wrinkled leaf, often strongly curled downward. There seems also to be a tendency to form more secondary branches than is normal, and as these remain short and have curly leaves the compactness of the plants is more striking. The stems are also very brittle.

COLOR OF THE FOLIAGE.

The color of the foliage in curly-dwarf is typically a normal green, except that in very severe or advanced cases there is a lighter green or yellow color sometimes accompanied by brown or reddish flecks in the leaves where the tissues are dying. Typical curly-dwarf is readily distinguished from leaf-roll by the wrinkled or downward curling of the leaves, the normal color of the foliage, and the firmness of the leaves, which do not lack turgidity.

The tuber yield of curly-dwarf plants is greatly curtailed. Severe cases have no tubers, and many such have been observed. In others a few small potatoes are formed. This difference in productivity is strikingly shown in the photograph reproduced in Plate XIII, figure 2, of the yield from curly-dwarf hills compared with adjoining healthy hills.

The nature and cause of this disease remain unknown. No evidence of fungi or other parasites have been found. There is neither browning nor mycelium in stems and tubers, but the curly-dwarf is transmitted through the seed. The hereditary nature of the trouble is attested by the German authorities, and it has been observed by the writer in the case of some hill selections made by Prof. Stuart in 1911 and planted in the Arlington greenhouses that winter. The tubers from diseased hills all developed into curly-dwarf plants, while those from healthy hills remained normal. Equally good evidence of the transmission of this diseased condition through the tubers was afforded by the Stuart seedling collection of 1913, which, as described under leaf-roll, was planted in 2-hill tuber units. No. 4033 had 4 pairs of curly-dwarf and 5 pairs of healthy hills in the following order: Two normal hills, 2 curly-dwarf, 2 normal, 2 curly-dwarf, 2 normal, 2 curly-dwarf, 2 normal, 4 curly-dwarf, 2 normal. No. 13016 had the first two hills normal, the next two curly-dwarf. No. 13372 had 4 normal hills, then 4 curly-dwarf, 1 normal, 1 curly-dwarf, and 2 normal. No. 14637 had hills Nos. 1 and 2 normal, and 3 and 4 curly-dwarf; and these examples might be multiplied many times. The few exceptions where single hills developed the disease may be due to an error in dropping the seed or to planting a small tuber whole.

OCCURRENCE AND DISTRIBUTION.

In Europe curly-dwarf is apparently not sufficiently common to have any economic significance. The literature on this subject must, however, be interpreted with an understanding of the confusion of terms among the older authors, who often used the word "Kräuselkrankheit" as a collective term for curly-dwarf, leaf-roll, bacterial ring disease, and still others (Appel and Schlumberger, 1911; Frank, 1897; Kühn, 1859). Evidence is also found in the old English literature that a varietal deterioration called "curl" was frequent even in the nineteenth century (Dickson, 1814; Shirreff, 1814; Townley, 1847; Foster, 1905). It is impossible to know whether this trouble was leaf-roll or curly-dwarf; but the thought suggests itself that there have been periods, or cycles, of decline in potato varieties, followed by the rejuvenation due to introduction of new sorts. It may be that such a period of decline is now beginning, as manifested by the appearance of leaf-roll and similar troubles in the principal potato countries during recent years.

In the United States it is probable that curly-dwarf plays a large rôle in the deterioration of potatoes. It is commonly met with in New England and New York fields, though not always recognized, as the larger plants overshadow and conceal the weaklings. The writer has sought this type of deterioration in potato fields in many States from Maine to California, and has found it to be not infrequent in occurrence, but that its presence in the average field is limited to scattered plants, usually less than 2 per cent. Field-to-field inspection in important potato districts has, however, resulted in the discovery of some fields where a larger percentage, even half or more of the plants, showed curly-dwarf. Some of these fields showed weakness in other ways, through failures to germinate, blackleg, mosaic disease, and general lack of vigor.

In another instance a strain of potatoes was being grown by a progressive, careful farmer, who had adopted the hill-selection method to increase vigor and productiveness, yet a considerable proportion went down with curly-dwarf in 1913, three years after the selection ceased. The 1912 crop was normal in appearance but was subjected to severe drought. This is of interest in connection with the belief that prevails in some quarters that dry years induce this type of trouble. The same grower shipped a portion of his 1912 crop to a southern State for the early spring planting, and much curly-dwarf appeared in the fields of the purchaser.

It seems evident that this is a physiological disorder, resulting in a permanent deterioration of the stock. It may develop at any time as a result of conditions not yet fully understood, and the vigor of the affected strain apparently can not be restored.

This is a problem in varietal decline that should receive earnest consideration. The prevalence of such weak plants should be ascertained in any stock intended for propagation, and measures undertaken to provide disease-free seed potatoes in sufficient quantity to meet all demands.

There are all grades of the condition above described, from pronounced types of curly-dwarf to those approaching normal vigor. It will furthermore be apparent that this is a difference inherent in the varieties or strains under observation. Schander has described a related condition as the "Barbarossa disease," so named because it is characteristic of the German variety Barbarossa. In every potato field are found some weaklings, or plants which are merely small, without any curled leaves or dwarfed stems, and without the fungous lesions described under "Rosette." The extent to which these small plants represent a permanent deterioration in the vigor of the stock, and thus a condition related to the curly-dwarf, is a problem not yet settled. Certainly such weaklings should be eliminated when improved seed is desired.

CONTROL OF CURLY-DWARF.

Since potatoes from diseased hills can not be restored to vigor, all such should be rejected for planting. The occurrence of any considerable number in a field may be taken as evidence of a general decline, requiring that the entire stock be given up and new seed substituted.

It has already been demonstrated by Prof. Stuart that we have in the method of tuber selection outlined by Webber (1908) a means by which all diseased potatoes may be eliminated from a stock, since when all tubers are cut into four pieces and these planted in adjacent hills all those which show inherited weakness may be eliminated and only the strongest and most productive selected.

ROSETTE.

Phases of leaf-roll and curly-dwarf marked by dwarfed growth and the formation of aerial tubers have been described. These symptoms may, however, result from another cause—the stem lesions due to *Rhizoctonia*, and no attempt to differentiate potato troubles can be successful which does not take into consideration the varied effects of this fungus. It must be recognized that *Rhizoctonia* appears to be a more active parasite in America than in Europe and to play a greater rôle in the Western States than in the Eastern.

Since this article is written primarily to effect a diagnosis of potato troubles, it will not be necessary to review the facts already well known to pathologists relative to the occurrence of *Rhizoctonia* on its various hosts or to discuss the relationship and parasitism of the several known strains. This subject is being fully reinvestigated

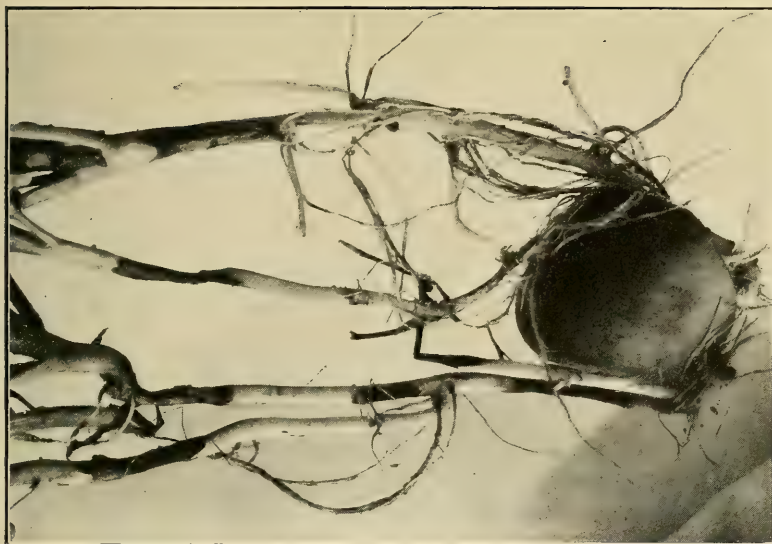


FIG. 2.—RHIZOCTONIA LESIONS AT THE BASE OF STEMS,
OFTEN PRODUCING THE ROSETTE EFFECT ON THE
FOLIAGE. (PHOTOGRAPHED BY H. B. SHAW, JEROME,
IDAHO, 1913.)

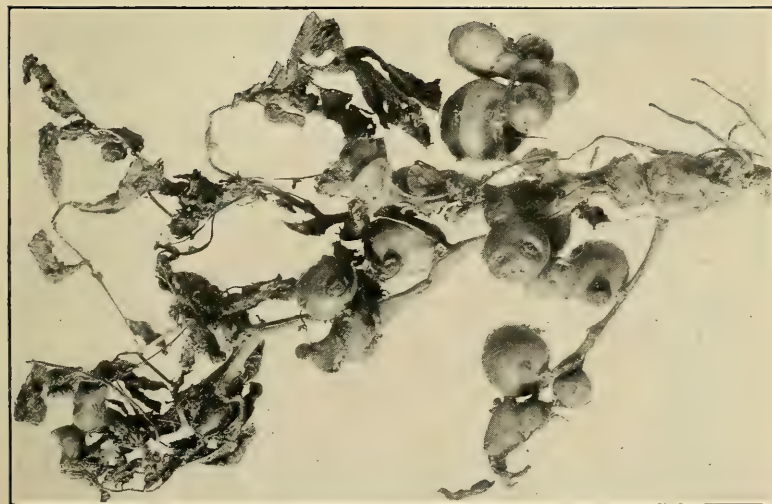


FIG. 1.—RHIZOCTONIA EFFECT ON POTATO, SHOWING
AERIAL TUBERS DUE TO LESIONS AT THE BASE OF
THE STEM. LA CONNER, WASH., SEPTEMBER,
1909.



FIG. 2.—HEALTHY EUREKA POTATO PLANT. (FOR COMPARISON WITH FIGURE 1.)



FIG. 1.—POTATO MOSAIC DISEASE. EUREKA VARIETY IN ARLINGTON GREENHOUSE, 1913.

by Dr. H. A. Edson, of the Bureau of Plant Industry. It is, however, important to mention that types of potato disease are not infrequently encountered which simulate in one character or another the leaf-roll, the curly-dwarf, and sometimes blackleg, but which is believed to be associated with *Rhizoctonia*, although it must be admitted that the proof is somewhat scanty.

This fungus is almost ubiquitous on potato tubers in its sclerotial form; small black mycelial masses superficially attached to the epidermis without evidence of parasitism may be found on tubers from every State. In other cases a russet scab or cracking is attributed to the same fungus, and lesions are formed on the underground stem and stolons. The fruiting stage, *Corticium vagum solani* Burt (*Hypochnus solani* Prill), is formed on the green stem above ground and is merely a superficial nonparasitic layer over healthy tissues.

The reaction of the potato plant to *Rhizoctonia* infection depends upon the part attacked. If this be the stolons, the young tubers are cut off, and this process, taking place in the heavy irrigated soils of the West, is held by Rolfs (1902, 1904) to be the cause of that type of potato failures in which large overgrown vines produce few or only small tubers. If the lesions encircle and girdle the main stem near the soil line, the result will be the formation of numerous aerial tubers (Pl. XV, fig. 1) formed as a result of the destruction of the phloem and the prevention of carbohydrate translocation. The same result would follow mechanical girdling. This type of injury sometimes results in a leaf-roll that is hard to distinguish from the genuine leaf-roll until the plant is pulled and the stem injury noted. Such plants were conspicuous in the Red River Valley in Minnesota in 1913. There may have been a complication with blackleg there, but there was no leaf-roll. In the San Luis Valley of Colorado, also, the *Rhizoctonia* injury is reported by Edson and Wollenweber to take a form strongly simulating leaf-roll.

Rhizoctonia lesions on the young hypocotyl, such as are figured in Plate XV, figure 2, cause a dwarfed growth described by Selby as rosette. The condition figured by him closely approaches curly-dwarf, and the question is well worth raising in the case of stunted plants bearing *Rhizoctonia* lesions whether their vigor had not been impaired prior to infection.

One can pass through potato fields in Ohio and Wisconsin, for example, and on pulling the small, weak, or rosette plants find many, but usually not all, with these stem lesions. So far as the writer knows, no one has planted the tubers from such hills to learn whether the weakness is transmissible. The case for *Rhizoctonia* is weakened, however, when one finds the stem lesion on vigorous, outwardly healthy hills as well as on the rosette examples. The subject clearly needs further investigation.

MOSAIC.

The potato mosaic is an abnormal condition of the foliage characterized by a spotted or mottled appearance of the leaves, portions of which are lighter green in color and with thinner, less perfectly developed parenchyma than the normal. In the later stages, brown flecks of dead tissues may appear. These light-green areas vary considerably in size in different cases, from definite patches of 5, 10, or 20 millimeters, with fairly distinct demarcation between diseased and healthy tissues, to an indefinite punctate type where a thin yellow-green spot of leaf tissue merges gradually into the apparently normal. The latter has been the more common on potatoes in the writer's observations to date, while the former is more frequent in the mosaic diseases of tobacco, tomato, and other plants. Reference to Plate XVI, figure 1 will make these points clearer than pages of text. There are phases of mosaic where it might be inferred that the plants under observation were of varieties having naturally irregular, curled, or wrinkled foliage, were it not for the contrast with the healthy plants alongside. (Pl. XVI, fig. 2.)

Cases of potato mosaic have been observed with the abnormal leaf areas so large and so clearly marked as to suggest variegations, such as are familiar among ornamental plants. True variegations occur somewhat rarely in potato foliage, but the writer has seen one variety all the plants of which had variegated green and yellow-white leaves. This sort, appropriately named the "Harlequin," was grown in 1911 in a variety test on the experimental grounds of the Landwirtschaftliches Institut at Goettingen, Germany. As might be expected, it was lacking in vigor as compared with the other varieties.

The effect of mosaic on the growth and development of potato plants is quite marked. Most conspicuous is the irregular, distorted, or wrinkled foliage. This effect is manifestly due to the imperfect development of the diseased portions of the leaf parenchyma. The plants are also smaller, except in the mildest cases. The effect on the yield was tested by harvesting 80 mosaic hills and 80 healthy hills of the Green Mountain variety, on September 10, 1913. The yield of the diseased plants was 94.4 pounds; and of the healthy, 120.8 pounds, a difference of 22 per cent.

Typical potato mosaic can not be confounded with typical curly-dwarf. The former is marked by abnormalities in the leaf parenchyma while the especial characteristic of the latter is the restricted development of the vascular elements. There do occur, however, some intergrading forms that present puzzles that will doubtless be cleared up later when both diseases have been more fully studied.

No references to potato mosaic have been found in the literature. It was first observed by the writer in 1911 in a field at Giessen, Germany, where it was not uncommon, especially on some varieties.

In 1912, it was exceedingly prevalent in some fields of Green Mountain in Aroostook County, Me. The number of plants affected varied from 1 per cent up to practically 100 per cent. Some fields of several acres were seen where hardly a normal plant could be found. The disease was present again in 1913 in the same district, always on the Green Mountain variety. Mosaic has not been found in the potato districts of Wisconsin, Minnesota, Colorado, or other Western States, though an extended survey of these States was made in 1912 and 1913.

There is evidently much difference in varietal susceptibility. Hundreds of fields were examined in Maine where the Green Mountain variety was growing side by side with Irish Cobbler, but practically no mosaic was observed in the latter, whereas it was very common in the former. There appears to exist also a corresponding difference in the tendency of strains or stocks of the same variety toward mosaic. Different fields of the Green Mountain variety showed from none to 100 per cent of diseased plants. An experiment in the Arlington greenhouses further demonstrated this point, though undertaken for another purpose—the control of silver scurf. Two greenhouse beds were planted with the variety Eureka, using seed from two sources. One lot showed 46 mosaic and 31 healthy plants, eliminating doubtful cases, or 59.7 per cent diseased. The second lot had 100 per cent free from mosaic. Portions of the first lot had been treated with formalin, corrosive sublimate, and heat, with control lots untreated. These treatments did not appreciably affect the proportions of mosaic which developed.

That mosaic is transmitted through the tubers is thought to be not improbable. An experiment to test this was carried out in Maine during the past season with somewhat inconclusive results. Tubers from mosaic hills marked in 1912 were planted in hill-unit rows, with controls. The progeny were in part mosaic and in part of a doubtful character, smaller and less vigorous than the controls, but with less clearly marked mosaic than the parent hills. On account of some confusion of the labels, it is thought best to repeat the test before drawing conclusions.

The cause of potato mosaic is unknown, nor have experiments been made to determine whether, like the mosaic of tobacco, it is communicable from plant to plant. Allard (1912) has shown that the tobacco mosaic can not be transferred from tobacco to potato by inoculation. The exact nature and relationship of potato mosaic to other similar troubles remains to be worked out. In this article, which is primarily diagnostic, it is aimed to point out that such a disease exists and that it may become a factor in the problem of varietal deterioration of such importance as to require consideration when selecting or inspecting seed stocks for certification or purchase.

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CEREBROSPINAL MENINGITIS ("FORAGE POISONING").

By JOHN R. MOHLER, V. M. D., *Chief of the Pathological Division.*

INTRODUCTION.

About 100 years ago (1813) there appeared in Wurttemberg a fatal disease of horses which was termed "head disease" owing to the pronounced manifestation of brain symptoms. The affection spread through certain sections of Europe from 1824 to 1828 and was described as "fever of the nerves." In 1878 the attention of the veterinarians of Saxony was attracted to the disease, which was then termed "nervous sickness," and within the next 10 years it assumed an epizootic character. In fact the malady became so prevalent in and around Borna (near Leipsic, Germany) during the nineties that it became known as the Borna disease. The affection has spread like a plague on two occasions in Belgium, and has also exacted a heavy toll in Russia, Great Britain, Austria-Hungary, and elsewhere. Its appearance in America is by no means of recent occurrence, for the malady was reported by Large in 1847, by Michener in 1850, and by Liautard in 1869 as appearing in both sporadic and enzootic form in several of the Eastern States. Since then the disease has occurred periodically in many States in all sections of the country, and has been the subject of numerous investigations and publications by a number of the leading men of the veterinary profession. It is prevalent with more or less severity every year in certain parts of the United States, and during the year 1912 the Bureau of Animal Industry received urgent requests for help from Colorado, Georgia, Iowa, Kansas, Kentucky, Louisiana, Maryland, Missouri, Nebraska, New Jersey, North Carolina, Oregon, South Carolina, South Dakota, Virginia, and West Virginia. While in 1912 the brunt of the disease seemed to fall on Kansas and Nebraska, other States were also seriously afflicted. In previous years, for instance in 1882 as well as in 1897, the horses of southeastern Texas were reported to have died by the thousand, and

NOTE.—This publication gives information about a serious disease of horses; it is especially suited to veterinarians in the States west of the Mississippi River and in the South.

in the following year the horses of Iowa were said to have "died like rats." However, Kansas seems to have had more than her share of this trouble, as a severe outbreak that extended over almost the entire State occurred in 1891, while in 1902 and again in 1906 the disease recurred with equal severity in various portions of the State.

NOMENCLATURE.

There has always been considerable discussion and criticism regarding the different names which have been given this malady, and various terms have been applied according as each author in past outbreaks has considered certain symptoms or lesions as the paramount feature of the affection. Thus the disease has been termed "cramp of the neck," "head disease," "mad staggers," "sleepy staggers," etc. Through the recent investigations of Grimm, Schmidt, and others it has been quite definitely established that "head disease," Borna disease, and cerebrospinal meningitis are one and the same, and Hutyrá and Marek have accepted this opinion and incorporated it in their "Special Pathology." While at first the Borna disease was considered as a form of cerebrospinal meningitis, the work of Johné and Ostertag (1900) indicated that it was an independent disease, because they failed to find any inflammatory changes in the central nervous system. Accepting this view, Friedberger and Fröhner have separated the two diseases in their "Theory and Practice," basing their differential diagnosis chiefly on the absence of inflammation in the brain and cord of Borna disease. However, since the publication of this excellent work in 1904, Oppenheim, Dexler, Schmidt, and others have shown conclusively that inflammatory lesions are present in the central nervous system, although Dexler has pointed out that in some cases it is necessary to make a systematic examination of a number of slides to discover the inflammatory changes. As a result the more recent writers have adopted the viewpoint that the two terms, Borna disease and cerebrospinal meningitis, are synonymous.

When this disease appeared with such severity in certain sections of the United States in the summer of 1912, there were a number of persons who claimed that it was the Borna disease appearing in the New World for the first time; others diagnosed it as a new horse disease, as influenza, parasitism (due to the palisade worm), paralysis similar to poliomyelitis (infantile paralysis) of man, epidemic cerebrospinal meningitis of man, and equine malaria from the fact that mosquitoes were prevalent and the horses were in lowlands. These erroneous diagnoses, while participated in to a certain extent by some veterinarians, were usually the opinions of physicians, chemists, bacteriologists who were not veterinarians, and others of limited veterinary experience. However, the vast majority of veterinary

practitioners recognized the disease as their old torment—cerebrospinal meningitis, staggers, or forage poisoning.

The latter name came into the literature of the disease as a synonym in 1900 following the investigation of an outbreak by Pearson. He was able to reproduce the disease in experiment horses by feeding them on damaged silage, and by giving them water to drink which had percolated through this silage. Doubtless influenced by the frequent absence of microscopic lesions of the central nervous system, and by the analogy between this disease and meat poisoning of man, Pearson proposed the name forage poisoning, which has been more or less in favor ever since. There are certain objections to this term, principally from the fact that it may suggest a form of poisoning produced by vegetation that is specifically poisonous, such as lupines, loco, larkspur, etc., or by ordinary forage that is poisonous of itself. This, however, was not the intention of Pearson, for by his analogy to meat poisoning it is evident that he did not wish to convey the impression that all forage was poisonous any more than all meat is poisonous. But when meat becomes contaminated with pathogenic bacteria, such as the *Bacillus enteritidis*, *B. botulinis*, etc., such meat is dangerous to man in the same manner that ordinary forage contaminated with certain unknown infective agents becomes dangerous to horses and produces forage poisoning. In other words, the forage is the carrier and not the primary factor in the disease. On the other hand, this term has a direct advantage in being readily understood in popular usage and in conveying to the layman's mind that an absolute change in feed is essential.

After years of study and experimentation it is the consensus of opinion of practically all investigators that the disease can be controlled effectively only by a total change of feed and forage; in other words, by preventive measures and not by medicinal treatment. That there is direct connection between ingestion of green forage, exposed pasturage, newly cut hay and fodder, and the development of the disease is quite obvious, and that the ingestion of such forage when contaminated is the most important factor is equally obvious, as almost 100 per cent of the cases in Kansas and over 95 per cent of the cases in Nebraska of which we have any record were maintained all or part of the time under such conditions. Even such negative history is not always dependable, as the owner on one farm informed the writer positively that the dead horses had eaten nothing except old hay and grain, but when notice was taken of the closely cropped grass in an adjacent pasture he innocently remarked that he always turned the work horses into the pasture over night. In fact in some sections "pasture disease" is the designation for this malady.

Other names which have been given to this affection are epizootic encephalo-myelitis, meningo-encephalitis and meningo-myelitis, enzootic cerebritis, leuco-encephalitis, etc., but the writer prefers the old-fashioned terms cerebrospinal meningitis for the scientific term and "blind staggers" for the lay term. That the symptom of staggering is one of the most common manifestations of the disease is shown by the clinical observations of Schmidt, who has made a close study of 415 cases, 377 of which developed staggering symptoms while standing or walking. The only symptom which occurred more frequently was the loss of appetite appearing in 410 animals, while the symptoms next in prominence were grinding of the teeth, which was observed in 349 cases, and difficulty in swallowing, which occurred in 335 cases.

ETIOLOGY.

Unfortunately no specific bacteria, fungus, virus, or other toxic principle has yet been found which can be considered as the cause of cerebrospinal meningitis in the horse. It is quite true that bacteriological investigation has given us a number of different organisms by an equal number of different investigators, each of whom has thought his particular organism to be the causative agent of the disease; but the fact remains that the four rules laid down by Koch have not been met with sufficient regularity to make the results satisfactory to the disinterested worker. Further investigations are necessary to decide which, if any, of the reported organisms is the true cause of the disease. That the disease may not have an etiological entity has been suggested by Weichselbaum, Hutyra, and Marek. This would seem quite probable if all the claims for the following different etiological factors were to be accepted. For instance, Siedamgrotsky and Schlegel incriminated a micrococcus as the cause of the disease. On the other hand, Johne found diplococci in the cerebrospinal fluid which he termed *Diplococcus intracellularis equi*. Again, Ostertag recovered streptococci in short chains from the blood, liver, urine, and brain of affected horses. These organisms he termed Borna streptococci. Harrison of Canada isolated a streptococcus from the brains of horses affected with cerebrospinal meningitis which was quite similar to Ostertag's, although it differed in forming capsules, staining by Gram's method, refusing to grow well on gelatin, and in proving virulent for laboratory animals. In Minnesota, Wilson and Brimhall have also incriminated a diplococcus as the cause of cerebrospinal meningitis of horses, cattle, sheep, and pigs, and proved it to be the *Diplococcus pneumoniæ* of Frankel. They likewise claimed to have isolated the *Micrococcus intracellularis meningitidis* of Weichselbaum from the central nervous system of a cow showing symptoms of spinal meningitis. This latter organism

is also reported to have been found by Christiana in primary sporadic meningitis in the horse and in a goat.

The remarkable part of all the above investigations is that each author considers his particular organism as the etiological factor of the disease, and the majority of these writers believe they have succeeded in producing the disease in horses by the inoculation of these differing agents. Some of these positive results are readily explained by the large quantity of turbid fluid injected under the dura. The inoculation of 5 and 10 c. c. doses of a heavy emulsion of any organism is likely to produce an irritation, and the inflammation set up by such foreign material will necessarily produce exudation with accompanying mechanical pressure, so that it is not surprising to read in the post-mortem notes of some of these cases that the meninges bulged through the opening on cutting through the bones of the skull.

Schmidt, of Dresden, is of the opinion that the nature of the infectious principle is not settled, and believes that the cocci and diplococci which have been described as causative factors will in future be deprived of their pathogenic relationship.

In two outbreaks of forage poisoning investigated by Moore, of Cornell, one gave negative results from a bacteriological standpoint, while in the other pure cultures of the colon bacillus were obtained from the brain.

Grimm, working in Zwick's laboratory in Berlin, isolated streptococci from horses affected with head disease or staggers, which were not essentially different from the Borna streptococci of Ostertag. Owing to the regularity with which these cocci were taken from the brains of horses with "head disease"—cocci which Grimm stated possessed slight, if any, properties necessary to make them causal factors of disease—the question arose whether the same microorganisms are not also found in the brains of healthy horses. Grimm obtained the heads of 10 horses which were killed at the Zoological Garden for the animals, and which were by examination found to be free from any indication of cerebrospinal meningitis. In the brains of these healthy horses he found cocci (staphylococci and streptococci), although cultures were made within a few hours after death, and at least one strain has shown many similarities to the streptococcus found by Ostertag.

These results of Grimm's work are very similar to the results of the Bureau of Animal Industry. In horses which have died of forage poisoning it is not a difficult task to recover various forms of cocci; in fact, too many forms to make them all of etiological significance, while in those cases which have been killed in the late stages of the disease it is of common occurrence to have all the culture media inoculated with the various tissues remain sterile. On the other hand, we found micrococci, diplococci, streptococci, and staphylococci so frequently

in the brains of horses which have died of dourine, swamp fever, influenza, etc., that we have come to consider these organisms as representing an agonal invasion from the intestines without causal connection with any definite disease. Like Grimm, we have found some of these same cocci in the brains of horses that died of forage poisoning, and we have also recovered other species, all of which have been inoculated into experiment horses by various methods, including intravenous, subcutaneous, subdural, and intralumbar injection, as well as by spraying the nasal mucous membrane, with the result that two horses died following a nasal douche and a subdural injection, respectively, of a pure culture of two different cocci. The post-mortem on the former showed death to have been due to a strangulated intestine, while the second animal died suddenly without evincing any characteristic symptoms, although extremely nervous. Post-mortem examination showed an absence of any pathological lesions posterior to the brain. The dura mater was inflamed and distended with a yellowish exudate. The veins and capillaries of the cerebrum were dilated and engorged with blood, while the third ventricle contained a tumor the size of a walnut. Although the same organism which was injected was recovered from the brain tissue, other horses injected with the recovered culture have continued to remain in a healthy condition.

With the view of obtaining additional information regarding the significance of these various cocci to the disease in question, an antigen was prepared from a culture of each organism and tested against the blood serum obtained from affected horses in the field for complement fixation and agglutination as in glanders. In no case was a positive reaction to these tests obtained by the use of any of the antigens prepared from the different cocci isolated from diseased horses. In this connection it may be noted that from the number of affections of the horse produced by coccoid organisms, this animal appears to be particularly susceptible to their action.

Another cause has been suggested for this disease in the finding of nuclear inclusions by Joest and Degen in the nerve cells of the hippocampus. These inclusions are similar to the Negri bodies of rabies, and are rounded or oval in shape, staining intensely with eosin. A large number of brains from affected horses have been examined in our laboratory for these bodies, but thus far with negative results, although the same technique applied to the brains of rabid animals brings out the Negri bodies with great clearness.

There remains one widely accepted theory as to the causation of the disease which must be given consideration, namely, fungi on the feed. While most investigators have obtained negative results when feeding experiment animals upon moldy feed, some few have reproduced the disease by such feeding. Thus, Mayo reports that a

colt fed experimentally upon some of the moldy corn, which was held responsible for the serious outbreak in Kansas in 1890, developed the disease and died on the twenty-sixth day. Again, the Kansas outbreak of 1906 was said by Haslam to have been produced by immature ears of corn infected by molds, although the exact mold was not discovered. By feeding horses upon this immature corn badly infected with molds, typical fatal cases of staggers were produced in four out of seven horses. Haslam also records the fact that severe losses of horses have occurred in other States when the grasses in the pastures became moldy. Klimmer, commenting upon the negative results obtained in experiments with moldy feed, asserts that the numerous losses occurring from the feeding of such material indicates the probability that the experiments were not sufficiently extensive from which to draw conclusions, and believes that the use of such feed should be discouraged. Among other writers who have attributed the disease to toxic fungi are Michener, Trumbower, and Harbaugh. The latter investigated the serious outbreak of this disease which occurred in Virginia and North Carolina in 1886, and claimed that every case of the disease could be traced directly to moldy feed.

This theory of toxic fungi is not antagonistic to the facts in many of the best observed outbreaks, and knowing that fungi vary greatly in growth and in the elimination of various products under different climatic conditions, we may explain the irregularity of the symptoms as well as the occurrence of the disease under what may appear to be identical conditions. Thus Ceni of Italy states that molds are capable of producing poisons, but only at certain stages of their growth, and at other times they are entirely inactive. A case of this character was investigated by this bureau several years ago in an outbreak among the United States Army horses at an encampment in Pennsylvania. Many horses had died of cerebrospinal meningitis as a result of eating moldy baled hay, and as soon as the hay was eliminated the deaths ceased. Other horses in the vicinity not fed upon this hay failed to contract the disease. At the suggestion of State Veterinarian Marshall the bales were opened and exposed to the sun for three or four weeks, after which time this hay was fed sparingly at first and later in usual quantities without producing any ill effect. Forage poisoning therefore seems to be an auto-intoxication rather than an infection, and due to certain chemical poisons or toxins formed by organismal activity. These toxins may be present when the forage is taken into the body or formed in the gastro-intestinal canal, and, therefore, the disease is a specific form of auto-intoxication. The nature of the substance which causes these harmful changes or the poisonous bodies that are formed remain unknown.

On account of this very old and very plausible theory so often advanced, that the disease is due to toxic substances existing in damaged grain and fodder, a number of species of fungi were isolated during the past year from damaged corn and forage and grown on a sterilized corn medium or alfalfa infusion in an effort to produce some toxic substance that would create disease when fed to horses. The pure cultures were allowed to grow for periods of one month's duration, in flasks containing 250 cubic centimeters of the nutrient medium, and the contents of one flask were fed each day for periods of 30 days, along with a sufficient quantity of sound corn and hay to make a normal ration; but no symptoms have thus far developed in the experiment animals, although only about one-half of the number of pure cultures isolated have thus far been used in this experiment.

It is possible that laboratory conditions alone can not be made to parallel sufficiently close those which exist naturally in the growing plants, and that toxic substances which might be produced in a natural state would not be generated in a corn-meal medium in the laboratory. The by-products of the growth of both fungi and bacteria on corn and forage should certainly receive more consideration in future work. In view of the above information it must appear to the unbiased mind that the cause of forage poisoning remains an obscure and puzzling problem.

OCCURRENCE.

Like cerebrospinal meningitis of man, forage poisoning occurs in sporadic as well as enzootic and epizootic forms. The sporadic cases occur either in different localities from the epizootic outbreaks or in such sparse numbers as not to amount to an enzootic. Thus the outbreaks are quite variable in extent and severity. Sometimes they become very widespread, causing heavy losses, as in the recent outbreak in Kansas and Nebraska, while at other times there are only sporadic cases. Liebenner believes that the development of the cause of the disease in Germany is favored by the rainfalls and warmth of the earth during summer and autumn. No conclusive evidence has ever been presented to indicate that the disease is ever transmitted directly from one horse to another. Sick animals have been placed alongside of susceptible horses in the same stable without conveying the disease to the latter, and healthy horses have been placed in stalls previously occupied by animals which died of the disease, and have eaten from the same mangers without previous disinfection, but in no case has the disease been transmitted in this manner. In the recent outbreak in Kansas it was quite noticeable that livery and other work horses were not affected so long as they were fed on clean, dry forage, although they were constantly exposed

to the disease by coming in contact with diseased horses. For instance, Dr. Herman Busman, who was in charge of the Kansas field force of veterinarians of the Bureau of Animal Industry, reports a case where horses were kept in adjoining corrals separated only by a wire fence. Those on one side were fed on green forage and recently cut cane, and died from the disease, while those on the other side were fed dry feed and not one became sick. He also reports a similar occurrence in a livery barn where the horses had been fed on clean, dry feed without sickness, but when fresh cut bottom-land hay was substituted for the former feed the horses became sick within a few days. Another similar instance was reported by Dr. E. T. Davison, in charge of the bureau's field force in Nebraska, in the case of a farmer who owned a work team that was strictly barn fed. While attending the State Fair at Lincoln these horses were turned out on pasture for two days and both horses came down with the disease on the fourth and fifth days, respectively, after being taken off the pasture.

It is such cases as these that have incriminated the forage and caused the disease to be known as "pasture disease" in some localities. Indeed some veterinarians report that all the animals affected had been on pasture, or, having been removed from pasture, had been fed on recent cuttings of alfalfa, prairie hay, cane, or kafir corn, while no cases came under observation where the animals had been on dry feed all summer.

A long period of dry weather followed by rainfall with considerable humidity and heat seems to favor the development and dissemination of the disease. The period from August 1 to October 1, 1912, presented exceptional climatic conditions in western Kansas and southern Nebraska, and it was observed that crops cut and cured before this date could be fed with impunity. During the first week in August a heavy rainfall started in Kansas and nearly twice the usual amount was recorded, falling mostly during the night and soaking in. This was followed by very high temperatures, the 17 days from August 23 to September 9 being the hottest series of days on record in Dodge City. There were also more than the usual number of cloudy or partly cloudy days with high relative humidities. The dew point was reached early at night and the deposit of dew was abundant, which is uncommon in that section. High humidities certainly continued throughout the day among the grasses near the soil. These grasses, which usually cure into hay on the root, became dotted with both parasitic and saprophytic fungi. Water holes, draws, and buffalo wallows remained filled with water throughout most of the period. During the latter part of September frosts occurred, accompanied not only by cooler weather but with lower

humidity, which are the significant factors in the subsidence of the disease, and after the first week in October the disease practically disappeared. Since then many owners have placed their horses back on the same pastures used during the serious stages of the disease and there has been no ill effect noted. This would indicate that there are good reasons to believe the forage is no longer in condition to produce the disease and hence its use is safe, as in the case of the Pennsylvania baled hay previously mentioned.

Somewhat similar conditions of climate obtained in Nebraska during the prevalence of the disease, but on September 25 a killing frost was recorded, followed by several light frosts and a reduction in the relative humidity. After this time the disease rapidly subsided and finally disappeared. There is not much question that some of this infected forage has been baled and shipped to various points, and it is therefore not unlikely that sporadic cases of the disease will appear in these sections under favorable climatic conditions.

In this connection, attention should be called to the marked prevalence last summer and fall of the disease of cattle known as mycotic stomatitis, which simulates the foot-and-mouth disease of Europe and is caused also by contaminated forage. This disease first appeared in Florida and spread over Georgia, North and South Carolina, Tennessee, Kentucky, Virginia, Maryland, and into Pennsylvania. The climatic conditions were evidently appropriate for the development of the causative agent on forage, and as soon as the animals were brought out of the pastures and stall fed, the disease immediately subsided.

SYMPTOMS AND LESIONS.

In most of the cases disturbance of the appetite, depression, and weakness are the first manifestations observed, although all the symptoms vary within wide limits.

Very soon the characteristic symptoms of the disease appear. There is trouble in swallowing, drooping of the head and sleepiness, which may give way to excitement and attacks of vertigo. An impairment of vision is noted, with loss of coordination, resulting in a staggering gait or reeling while standing. There is muscular twitching, cramp of certain muscles, chiefly of the neck and flanks, and grinding of the teeth. Sometimes colicky pains are noted. If in an open space, the animal will walk in a circle, sometimes to the right, at other times to the left, and will try to push through any obstacle with which he comes in contact. In the stable he will press his head against the stall or rest it on the manger. Sometimes he will crowd backward or sidewise until he gets in a corner and remains there. If the temperature is taken at the beginning of the disease it will be

found to be from 103° to 107° F., but within 24 hours the temperature gradually falls until it reaches normal and then becomes subnormal. The pulse is from 40 to 90 and weak, while the respirations are fluctuating from normal to as high as 48 per minute. There may or may not be drooling of saliva, depending on the extent of the paralysis of the pharynx. The animal is often down on the second or third day and may or may not get up when urged to do so. While down he will go through automatic-like movements of pacing or walking, resulting in acceleration of the pulse and respiration. At this time the legs are held out stiffly and parallel to the ground. The hind legs of many of these animals that have gone down are paralyzed and there is loss of sensation of the skin of these parts. The expired air is extremely fetid, and there may be a croupous-like deposit of the throat, which has caused the name "putrid sore throat." The conjunctiva may show injected blood vessels or petechiæ on a yellowish-tinted background. Coma or somnolence may be marked in animals going down within the first few days. Those which remain standing may become violent or delirious, but ordinarily the horse is tractable and easily managed. Death usually occurs in from 4 to 8 days, although in the acute form death may follow within 10 or 12 hours after the first symptoms are observed, while in chronic cases the disease may last 2 or 3 weeks. The prognosis is very unfavorable, as 85 to 90 per cent of the affected animals die, in the beginning of the outbreak, but later the cases become milder with a consequent drop in the mortality.

On post-mortem the amount of lesions observable to the naked eye is in marked contrast to the severity of the symptoms noted. The pharynx and larynx are inflamed in many cases, and sometimes coated with a yellowish white glutinous deposit, extending at times over the tongue and occasionally a little way down the trachea. The lungs are normal, except from complications following drowning or recumbence for a long period. The heart is usually normal in appearance, except an occasional cluster of petechiæ on the epicardium, while the blood is dark and firmly coagulated. The mucosa of the stomach indicates a subacute gastritis, while occasionally an erosion is noted. An edematous, gelatinous infiltration is observed in the submucosa of such cases. The first few inches of the small intestines likewise may show slight inflammation in certain cases, while in others it is quite severe; otherwise the digestive tract appears normal, excluding the presence of varying numbers of bots, *Strongylus vulgaris*, and a few other nematodes. The liver is congested and swollen in some cases, while it appears normal in others. The spleen is, as a rule, normal, and at times the kidneys are slightly congested. The bladder is often distended with dark-colored urine, and occasionally a marked cystitis has been observed. The adipose tissue

throughout the carcass may show a pronounced icteric appearance in certain cases. On removing the bones of the skull the brain appears to be normal macroscopically in a few instances, but in most cases the veins and capillaries of the meninges of the cerebrum, cerebellum, and occasionally the medulla are distinctly dilated and engorged, and in a few cases there are pronounced lesions of a leptomeningitis. An excessive amount of cerebrospinal fluid is present in most of the cases. On the floor of the lateral ventricles of several brains there was noted a slight softening due to hemorrhages into the brain substance. There is always an abundance of fluid in the subarachnoid spaces, ventricles, and at the base of the brain, usually of the color of diabetic urine, and containing a limited amount of flocculi, but in a few cases it was slightly blood tinged. The spinal cord was not found involved in the few cases examined.

A comparative microscopic examination of the brains of horses which died in Kansas, New Jersey, Maryland, and Virginia this year with those of horses from previous outbreaks showed the same characteristic perivascular round-cell infiltration, especially in the olfactory lobe and the hippocampus. The pia mater showed an increased amount of connective tissue with dense round-cell infiltration which extended into the adjacent cortical portion of the cerebrum. The capillary blood vessels were engorged with cells and their walls were greatly infiltrated. Limited areas of leucocytic infiltration and small hemorrhages in the brain tissue were not infrequently observed. No cellular inclusions in the ganglionic cells were detected after prolonged examination.

TREATMENT.

One attack of the disease does not confer immunity. Horses have been observed which have recovered from two attacks, and still others that recovered from the first but died as a result of the second attack.

Inasmuch as a natural immunity does not appear after an attack of cerebrospinal meningitis, it might be anticipated that serum of recovered cases would possess neither curative nor prophylactic qualities. Nevertheless, experiments were made along these lines with serum from recovered cases, but without any positive results. Similar investigations have been conducted by others in Europe with precisely the same results. With the tendency of the disease to produce pathological lesions in the central nervous system, it seems scarcely imaginable that a medicinal remedy will be found to heal these foci, and even where recovery takes place there is likely to remain some considerable disturbance in the functions, as blindness, partial paralysis, dumbness, etc. Indeed, when the disease once becomes established in an animal, drugs seem to lose their physio-

logical action. Therefore, with all the previously mentioned facts before us, it is evident that the first principle in the treatment of this disease is prevention, which consists in the exercise of proper care in feeding only clean, well-cured forage and grain and pure water from an uncontaminated source. These measures when faithfully carried out check the development of additional cases of the disease upon the affected premises.

While medicinal treatment has proved unsatisfactory in the vast majority of cases, nevertheless the first indication is to clean out the digestive tract thoroughly, and to accomplish this prompt measures must be used early in the disease. Active and concentrated remedies should be given, preferably subcutaneously or intravenously, owing to the great difficulty in swallowing, even in the early stage. Arecolin in one-half grain doses, subcutaneously, has given as much satisfaction as any other drug. After purging the animal the treatment is mostly symptomatic. Intestinal disinfectants, particularly calomel, salol, and salicylic acid, have been recommended, and mild antiseptic mouth washes are advisable. Antipyretics are of doubtful value, as better results are obtained, if the temperature is high, by copious cold-water injections. An ice pack applied to the head is beneficial in case of marked psychic disturbance. One-ounce doses of chloral hydrate per rectum should be given if the patient is violent or muscular spasms are severe. If the temperature becomes subnormal, the animal should be warmly blanketed, and if much weakness is shown this should be combated with stimulants, such as strychnin, camphor, alcohol, atropin, or aromatic spirits of ammonia. Early in the disease urotropin (hexamethylenamin) in doses of 25 grains, dissolved in water and given by the mouth every two hours, appeared to have been responsible for the recovery of some cases of the malady. During convalescence the usual tonic treatment is indicated.

Many of the so-called "cures" made their reputation at the time the outbreak was abating and when noninterference was proved to be equally effective. One of the most unpleasant developments of the outbreak in 1912 was the great amount of "faking," which seemed to be the only contagious feature connected with the disease. All kinds of drug specifics, serums, and vaccines developed like mushrooms and were exploited in almost every community devastated by the disease. Many tainted dollars were obtained from the suffering horse owners, who grasped at every newly advanced treatment like drowning men clutching at straws. In Nebraska, blackleg vaccine was reported to have been used as a preventive on at least 1,600 horses, and nearly 1,500 of them are said to have died as a direct result of the vaccine. This feature is now being investigated by the Government.

Dr. Munn, of Kearney, Nebr., had apparently good success from the use of diphtheria antitoxin as a prophylactic agent, since not a single animal developed the disease out of over 500 injected. It may be with this treatment, as with others, that good results were due to the fact that the disease was on the wane before treatment was commenced, but no other line of treatment gave as good apparent results. Dr. Kaupp also reports in the *Breeders' Gazette* that only 1 horse died out of 900 inoculated with a diplo-streptococcic bacterin he prepared, but the injections were made so late in the outbreak that its value is still problematical, since thousands of horses in the affected area at this period failed to develop the disease, although they had received no preventive treatment whatsoever.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

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Contribution from the Bureau of Statistics, L. M. Estabrook, Chief.
March 10, 1914.

STATISTICS OF SUGAR IN THE UNITED STATES AND ITS INSULAR POSSESSIONS, 1881-1912.

Compiled under the direction of FRANK ANDREWS,
Assistant Chief of the Division of Crop Estimates.

INTRODUCTION.

This bulletin was compiled primarily to have in convenient form data to answer numerous inquiries concerning the statistics of sugar in the United States and its insular possessions. Much of the data were obtained from existing publications, but it was found advisable to compile a number of new tables in order to present other facts of timely importance.

There was a great increase in the consumption of sugar in contiguous United States during the period covered by the bulletin, 1881-1912. The average consumption per capita in the latter part of this period was nearly double that of the early eighties. The average annual consumption, which in the fiscal years 1881-1885 was 46 pounds per capita, was more than 78 pounds in 1906-1910 (Table 2). The total annual consumption increased from an average of 2,500,000,000 pounds in 1881-1885 to practically 7,000,000,000 pounds in 1901-1910, and in the fiscal year 1912, to a total of 7,900,000,000 pounds (Table 2).

The large increase in consumption was coincident with a greater home production. The cane-sugar output increased considerably, while beet sugar, the production of which amounted to little in the early eighties, far exceeded that of cane sugar in contiguous United States in the last few years. The term "contiguous" applies to the United States proper, and excludes all outlying possessions.

The sugar supply of the United States proper has always been derived chiefly from abroad, and, even with a greatly increased home production in 1906-1910, the portion of supply received from domestic factories made only 23 per cent of the total consumption; this was more than twice the corresponding percentage for 1881-1885. The insular possessions—Hawaii, Porto Rico, and the Philippine

NOTE.—This bulletin, which indicates the amount and sources of the sugar supply of the United States, is of especial interest in sugar-producing regions, also to persons concerned with problems of food supply.

Islands—furnished nearly 22 per cent, and the rest, amounting to 55 per cent, came from foreign countries during 1906-1910.

The beet-sugar industry in the United States is not localized, as is the cane-sugar industry. Beets are grown and beet sugar is made in localities more or less scattered, in various regions extending all the way from Ohio to California, including on the north Minnesota and Montana and at the south Arizona. About two-thirds of the beet sugar made in the United States comes from the factories of California, Colorado, and Michigan. In 1912, the year of highest production up to date, 73 factories were in operation, with an average output of 9,500 short tons per factory for the campaign. The year before, the 66 factories then in operation made an average of about 9,000 tons each. The beet-sugar campaign averages from 80 to 90 days a year.

While cane is produced in considerable quantities in the Southern States, especially in those bordering the Gulf of Mexico, it is not used for manufacture into sugar to any noteworthy extent except in Louisiana and a few localities in Texas. Throughout most of the cane-producing area sirup, not sugar, is made. Census returns indicate that the output of cane sirup in contiguous United States increased from 13,000,000 gallons in 1899 to 23,000,000 gallons in 1909. Molasses, a by-product of sugar making, increased from 12,000,000 gallons in 1899 to 25,000,000 gallons 10 years later (Table 9).

All but a small fraction of the domestic cane sugar in contiguous United States comes from the southeastern quarter of Louisiana. Production in this State within the past few years has exceeded 340,000, and even 350,000, short tons annually, showing that the industry has been a progressive one, the output in earlier years having been much less. In 1912, however, owing to floods which injured cane fields, the Louisiana production dropped to about 154,000 short tons, while the number of factories in operation was only 126 as compared with 188 in the previous campaign. The length of the campaign was also reduced to about 30 days' actual operation in 1912 as compared with more than twice that time in 1911. A large part of the sugar made in Louisiana factories is shipped to New Orleans, most of it reaching that city about the last of December, which is practically the end of the sugar-making season. During the past five years more than three-fourths of the total receipts of Louisiana sugar at New Orleans arrived there before the end of December.

Data collected by the United States Department of Agriculture show that in 1911 about 2,000 pounds of sugar on an average were made from an acre of cane in Louisiana. This refers only to cane used for sugar and does not include that used for seed, which amounts to an average of about 1 acre in a total of 5, nor does it include cane used for sirup making. In the same year an acre of beets, in the

United States, yielded on an average about 2,500 pounds of sugar. In Hawaii the average yield of sugar per acre of cane used for manufacture amounted to about 8,700 pounds in the campaign beginning in the fall of 1910, and about 9,500 pounds in the campaign of the following year. The crop failure in Louisiana in 1912 reduced the average yield of sugar to less than 1,400 pounds per acre of cane. The average yield per acre of beet sugar in that year in the United States was about the same as in 1911 (Table 5).

Imports of foreign sugar into the United States, a very small fraction of which is received into the island possessions, come principally from Cuba and the Dutch East Indies (Tables 19 and 20). In 1901-1905 considerable amounts, nearly 24 per cent of the total imports into the United States, came from British Guiana, Brazil, Santo Domingo, Peru, British West Indies, and Germany, but during the next five-year period these countries supplied only about 7.5 per cent. In 1906-1910, Cuba's share in this trade increased to 73 per cent; in 1901-1905 it was 50 per cent of the total. Nearly all the sugar imported into the United States, and practically all that comes from the insular possessions, is raw (Table 21). Scarcely one-tenth of 1 per cent of the total imports during 1911 and 1912 consisted of refined sugar. The chief ports through which foreign sugar comes into the United States are New York, Philadelphia, Boston, New Orleans, and San Francisco (Table 22).

The output of the Hawaiian and Porto Rican sugar mills is sent almost exclusively to the United States; only a small fraction, about 10 per cent in the case of Porto Rico and 1 or 2 per cent in the case of Hawaii, is retained for home consumption (Table 23). Some details concerning the Hawaiian industry are reported regularly to the Bureau of Statistics of the United States Department of Agriculture. In the past several years 50 factories have been in operation. Nominally the campaign begins on October 1 and continues for varying lengths of time in the different factories; the average duration of the campaign in all the factories in 1911-12 was 200 working days. One or more factories have reported operations continuing practically throughout the year (Table 24).

As in contiguous United States so in the possessions, the production of sugar has increased greatly. The Hawaiian cane-sugar output is roughly commensurate in quantity with the beet-sugar production of contiguous United States; the Porto Rican production is roughly commensurate with that of Louisiana; while the surplus from the Philippine Islands, as represented by exports, is equal approximately to one-half of the Porto Rican crop. Of the sugar-producing countries of the world the United States with its insular possessions ranks among the first four. In the campaign 1911-12, owing to greatly increased crops in this country and its possessions and to low yields in Europe, the United States was second, being

exceeded only by British India. This large home production furnishes a little more than one-half of the home supply, the rest being brought from abroad. The United States leads all countries as an importer of sugar (Table 28).

Somewhat more than one-half of the "world" output of sugar is made from cane. According to Table 30, the proportion of cane sugar increased from 50.8 per cent of the total in the five years ending with 1905-6, to 53.3 per cent in the next five-year period. Measured in short tons, the cane-sugar product of the world increased from a yearly average of 7,200,000 tons in the first five-year period to 8,800,000 in the second; while beet sugar increased from 7,000,000 tons in the first to 7,700,000 in the second period shown in Table 30.

Of the leading countries of production, Cuba, Dutch East Indies (chiefly Java), and Germany are leaders in the export sugar trade of the world.

TABLE 1.—*Production of sugar in the United States and its insular possessions, 1881-1912.*¹

Year of cane or beet harvest.	Beet.	Cane.						Total beet and raw cane.	Total beet and cane in terms of refined. ³
	Chiefly refined.	Raw (as coming from factories).							
	Contiguous United States.	Contiguous United States. ²	Hawaii.	Porto Rico.	Philippine Islands (ex-ports).	Total raw cane.	Total cane in terms of refined. ³		
Average:	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.	Short tons.
1881-1885.....	692	132,148	76,075	87,441	189,277	484,941	436,447	485,633	437,139
1886-1890.....	1,922	171,488	125,440	70,112	186,129	553,169	497,852	555,091	499,774
1891-1895.....	19,406	275,289	162,538	63,280	286,629	787,736	708,962	807,142	728,368
1896-1900.....	58,286	286,805	282,585	61,292	134,722	765,404	688,864	823,690	747,150
1901-1905.....	239,730	364,179	403,308	141,478	108,978	1,017,943	916,149	1,257,673	1,155,879
1906-1910.....	479,153	362,208	516,041	282,136	145,832	1,306,217	1,175,596	1,785,370	1,654,749
1901.....	184,606	364,325	355,611	103,152	75,011	898,099	808,289	1,082,705	992,895
1902.....	218,406	372,903	437,991	100,576	123,108	1,034,578	931,120	1,252,984	1,149,526
1903.....	240,604	278,070	367,475	138,096	82,855	866,496	779,846	1,107,100	1,020,450
1904.....	242,113	414,995	426,248	151,088	125,271	1,117,602	1,005,842	1,359,715	1,247,955
1904 (census).....	253,921								
1905.....	312,920	390,602	429,213	214,480	138,645	1,172,940	1,055,646	1,485,860	1,368,566
1906.....	483,612	272,160	440,017	206,864	132,602	1,051,643	946,479	1,535,255	1,430,091
1907.....	643,628	394,240	521,123	230,095	167,242	1,312,700	1,181,430	1,776,328	1,645,058
1908.....	425,884	414,400	535,156	277,093	123,876	1,350,525	1,215,473	1,776,409	1,641,357
1909.....	512,469	375,200	517,090	346,786	140,783	1,379,859	1,241,873	1,892,328	1,754,342
1909 (census).....	501,682	334,202		283,223					
1910.....	510,172	355,040	566,821	349,840	164,658	1,436,359	1,292,723	1,946,531	1,802,895
1911.....	599,500	360,874	595,038	371,076	205,046	1,532,034	1,378,831	2,131,534	1,978,331
1912.....	692,556	162,574	546,524						

¹ Sources of data for contiguous United States for individual years: Cane sugar, 1881-1903 from Bouchereau; 1904-1906 from Bouchereau (for Louisiana) and Willett & Gray (for Texas); 1906-1910 from Willett & Gray; 1911 and 1912 from U. S. Department of Agriculture (for Louisiana) and Willett & Gray (for Texas). Beet sugar, 1897, 1901-1912, from U. S. Department of Agriculture; for other years from Willett & Gray. Hawaii: 1881-1884 from Rueb & Co.; 1885-1900 from Willett & Gray; 1901-1910 from Hawaiian Sugar Planters' Association; 1911 and 1912, U. S. Department of Agriculture. Porto Rico: 1881-1884 from Rueb & Co.; 1885-1889 from Willett & Gray; figures for 1900-1906 represent shipments from Porto Rico to the United States; 1907 and subsequent years (crops) from Treasury Department of Porto Rico. Philippine Islands (exports): 1894-1898 from Willett & Gray; other years from official sources.

² The term "contiguous" applies to the United States proper, and excludes all outlying possessions.

³ Raw sugar reduced to terms of refined by assuming 90 pounds of refined to be the product of 100 pounds of raw.

TABLE 2.—*Production and consumption of sugar in contiguous United States, 1881-1912.*¹

Year ending June 30—	Production. (Raw and re- fined.)	Receipts from foreign coun- tries and non- contiguous possessions. (Chiefly raw.)	Shipments to foreign coun- tries and non- contiguous possessions. (Chiefly refined.)	Retained and received for consumption. (Chiefly raw.)	
				Total.	Per capita.
Average:	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1881-1885	262,144,884	2,309,773,359	85,134,562	2,486,783,681	46.30
1886-1890	305,158,426	2,844,564,763	101,544,811	3,045,778,378	50.76
1891-1895	568,556,653	3,745,227,214	50,651,458	4,263,132,409	64.23
1896-1900	652,723,591	3,900,700,448	24,664,782	4,528,759,257	62.02
1901-1905	1,070,361,108	4,687,554,122	23,551,287	5,734,363,943	70.93
1906-1910	1,615,021,531	5,430,205,887	82,171,200	6,963,056,218	78.29
1901	795,938,283	4,803,085,602	14,015,102	5,585,008,783	71.96
1902	1,097,862,181	3,936,286,281	15,175,805	5,018,972,657	63.35
1903	1,182,617,560	5,217,077,034	19,529,092	6,380,165,502	78.92
1904	1,007,161,087	4,696,347,312	41,607,988	5,661,900,411	68.66
1905	1,268,226,430	4,784,974,378	27,428,446	6,025,772,362	71.66
1906	1,391,921,228	5,136,478,685	37,105,110	6,491,294,803	75.74
1907	1,511,544,000	5,621,004,778	42,879,843	7,089,668,935	81.19
1908	1,715,736,430	4,918,772,831	43,686,270	6,590,822,991	74.11
1909	1,680,568,000	5,700,675,377	97,879,825	7,283,363,552	80.43
1910	1,775,338,000	5,774,097,763	189,304,952	7,360,130,811	79.85
1911	1,730,425,000	5,594,985,191	89,436,445	7,235,973,746	77.15
1912	² 1,920,748,000	6,044,322,872	102,862,003	² 7,862,208,869	² 82.40

¹ Compiled from the Statistical Abstract of the United States, Bureau of Foreign and Domestic Commerce, Department of Commerce. Data for production for years ending June 30, 1904, 1905, and 1906, include cane-sugar production as estimated by Willett & Gray, which figures are lower than the estimates of Bouchereau, which are used in Tables 1 and 4, of this circular. If Bouchereau's estimates were substituted for Willett & Gray's in the above table, the figures for 1904, 1905, and 1906, respectively, would be: For production, 1,037,309,087, 1,314,226,430, and 1,407,041,228 pounds; and for consumption per capita, 69.02, 72.21, and 75.92 pounds. See also note 2, Table 1.

² Revised figures; substituted for the preliminary figures given in the original.

TABLE 3.—Percentage of total supply of sugar in contiguous United States represented by home production, by receipts from insular possessions, and by imports from foreign countries, 1881–1912.¹

[Chiefly raw.]

Year ending June 30—	Production in contiguous United States.			Received from Hawaii, Porto Rico, and Philippine Islands.	Imports less exports. ² (Net receipts from foreign countries.)	Retained and received for consumption.
	Beet.	Cane.	Total.			
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1881.....	(³)	13.0	13.0	14.4	72.6	100
1882.....	(³)	8.0	8.0	16.3	75.7	100
1883.....	(³)	13.2	13.2	15.9	70.9	100
1884.....	(³)	10.2	10.2	18.8	71.0	100
1885.....	0.1	8.4	8.5	18.9	72.6	100
1886.....	.1	10.7	10.8	20.5	68.7	100
1887.....	.1	6.1	6.2	19.1	74.7	100
1888.....	(³)	12.5	12.5	20.5	67.0	100
1889.....	.1	11.2	11.3	16.5	72.2	100
1890 ⁴	.2	9.4	9.6	17.6	72.8	100
1891.....	.2	12.8	13.0	9.0	78.0	100
1892.....	.3	9.5	9.8	11.2	79.0	100
1893.....	.6	11.7	12.3	12.0	75.7	100
1894.....	.9	12.4	13.3	10.7	76.0	100
1895.....	1.0	16.9	17.9	9.2	72.9	100
1896.....	1.5	12.1	13.6	12.9	73.5	100
1897.....	1.5	11.5	13.0	10.5	76.5	100
1898.....	2.6	20.4	23.0	18.1	58.9	100
1899.....	1.6	12.3	13.9	13.5	72.6	100
1900 ⁴	3.7	7.2	10.9	14.0	75.1	100
1901.....	3.1	11.2	14.3	14.9	70.8	100
1902.....	7.4	14.5	21.9	18.2	59.9	100
1903.....	6.8	11.7	18.5	16.0	65.5	100
1904.....	8.5	9.3	17.8	18.7	63.5	100
1905.....	8.0	13.0	21.0	19.6	59.4	100
1906.....	9.6	11.8	21.4	18.9	59.7	100
1907.....	13.6	7.7	21.3	17.7	61.0	100
1908.....	14.1	11.9	26.0	24.0	50.0	100
1909.....	11.7	11.4	23.1	21.9	55.0	100
1910.....	13.9	10.2	24.1	25.2	50.7	100
1911.....	14.1	9.8	23.9	26.1	50.0	100
1912 ⁶	15.3	9.2	24.5	30.2	45.3	100
Average:						
1881–1885.....	(³)	10.5	10.5	17.1	72.4	100
1886–1890.....	.1	9.9	10.0	18.8	71.2	100
1891–1895.....	.6	12.7	13.3	11.1	75.6	100
1896–1900.....	2.1	12.3	14.4	13.5	72.1	100
1901–1905.....	6.8	11.9	18.7	17.4	63.9	100
1906–1910.....	12.6	10.6	23.2	21.6	55.2	100

¹ Partly computed and partly copied from Statistical Abstract of the United States. For explanation of production figures for years ending June 30, 1904–1906, see note 1, Table 2. See also note 2, Table 1.

² Excluding trade with Hawaii, Porto Rico, and Philippine Islands.

³ Less than 0.05 of 1 per cent.

⁴ Census figures for production.

⁶ Revised figures for production and consumption substituted for the preliminary figures given in original.

TABLE 4.—*Comparison of cane and beet sugar produced in contiguous United States, 1881-1912.*¹

[In terms of refined sugar. Raw sugar has been reduced to terms of refined by assuming 90 pounds of refined to be the product of 100 pounds of raw.]

Year of cane or beet harvest.	Cane sugar.		Beet sugar.		Total.
	Quantity.	Per cent of total.	Quantity.	Per cent of total.	
Average:	<i>Short tons.</i>	<i>Per cent.</i>	<i>Short tons.</i>	<i>Per cent.</i>	<i>Short tons.</i>
1881-1885.....	118,934	99.4	692	0.6	119,626
1886-1890.....	154,339	98.8	1,922	1.2	156,261
1891-1895.....	247,760	92.7	19,406	7.3	267,166
1896-1900.....	258,124	81.6	58,286	18.4	316,410
1901-1905.....	327,761	57.8	239,730	42.2	567,491
1906-1910.....	325,987	40.5	479,153	59.5	805,140
1901.....	327,892	64.0	184,606	36.0	512,498
1902.....	335,612	60.6	218,406	39.4	554,018
1903.....	250,263	51.0	240,604	49.0	490,867
1904.....	373,496	60.7	242,113	39.3	615,609
1905.....	351,542	52.9	312,920	47.1	664,462
1906.....	244,944	33.6	483,612	66.4	728,556
1907.....	354,816	43.4	463,628	56.6	818,444
1908.....	372,960	46.7	425,884	53.3	798,844
1909.....	337,680	39.7	512,469	60.3	850,149
1910.....	319,536	38.5	510,172	61.5	829,708
1911.....	324,787	35.1	599,500	64.9	924,287
1912.....	146,316	17.4	692,556	82.6	838,872

¹ For sources see Note 1, Table 1. See also Note 2, Table 1.TABLE 5.—*Average yield of refined sugar per acre of beets or cane in contiguous¹ United States, and of cane in Hawaii.*

[Raw cane sugar has been reduced to terms of refined by assuming 90 pounds of refined to be equivalent to 100 pounds of raw.]

Item.	Pounds per acre.	Item.	Pounds per acre.	Item.	Pounds per acre.	Item.	Pounds per acre.
BEET SUGAR.		BEET SUGAR—continued.		BEET SUGAR—continued.		BEET SUGAR—continued.	
United States:		Colorado:		Utah and Idaho:		Other States:	
1901.....	2,109	1904.....	2,802	1904.....		1904.....	2,189
1902.....	2,019	1905.....	2,133	1905.....	2,678	1905.....	1,626
1903.....	1,984	1906.....	3,014	1906.....	1,783	1906.....	1,893
1904.....	2,448	1907.....	2,652	1907.....	3,124	1907.....	1,895
1905.....	2,036	1908.....	2,047	1908.....	3,020	1908.....	2,115
1906.....	2,572	1909.....	2,455	1909.....	2,794	1909.....	2,051
1907.....	2,499	1910.....	2,533	1910.....	2,948	1910.....	2,200
1908.....	2,334	1911.....	2,888	1911.....	2,642	1911.....	2,367
1909.....	2,439	1912.....	2,979	1912.....	2,294	1912.....	2,359
1910.....	2,563				2,962		
1911.....	2,530						
1912.....	2,494						
California:		Michigan:		Wisconsin:		CANE SUGAR.	
1904.....	2,845	1904.....	1,931	1904.....	2,484		
1905.....	2,850	1905.....	1,708	1905.....	2,035	Louisiana:	
1906.....	3,084	1906.....	1,886	1906.....	2,263	1911.....	2,023
1907.....	3,082	1907.....	1,918	1907.....	2,561	1912.....	1,348
1908.....	2,886	1908.....	2,104	1908.....	2,493	Hawaii:	
1909.....	3,067	1909.....	1,890	1909.....	2,453	1910-11.....	8,720
1910.....	3,091	1910.....	2,370	1910.....	2,162	1911-12.....	9,478
1911.....	3,241	1911.....	1,721	1911.....	2,034		
1912.....	2,852	1912.....	1,530	1912.....	2,306		

¹ See note 2, Table 1.

TABLE 6.—*Sugar-beet and beet-sugar production of the United States, 1901–1912, by principal States.*

State and year.	Facto- ries in opera- tion.	Sugar beets.			Sugar made. (Chiefly refined.)		Average ex- trac- tion of sugar based on weight of beets.	Average sugar in beets.	Average purity coeffi- cient of beets. ¹	Average length of cam- paign.
		Area har- vested.	Beets used for sugar.	Average per acre.	Pounds.	Short tons.				
California:	No.	Acres.	Short tons	Short tons.			Per cent.	Per cent.	Per cent.	Days.
1904.	.....	32,801	395,452	12.06	93,311,900	46,656	11.80	15.74	81.13	79.5
1905.	.....	51,857	514,391	9.92	147,786,900	73,893	14.37	17.27	81.33	91.5
1906.	8	60,141	671,571	11.17	185,480,000	92,740	13.81	16.70	82.70	115.0
1907.	8	47,387	484,816	10.23	146,045,500	73,023	15.06	17.90	85.10	73.0
1908.	8	62,302	647,085	10.39	179,780,000	89,890	13.89	17.66	83.20	88.0
1909.	10	83,000	882,084	10.63	254,544,000	127,272	14.43	17.61	83.62	102.0
1910.	8	90,500	923,100	10.20	279,780,000	139,890	15.15	18.20	82.78	114.0
1911.	10	99,548	1,037,283	10.42	322,600,000	161,300	15.55	18.85	82.04	98.5
1912.	11	111,416	1,004,328	9.01	317,808,000	158,904	15.82	18.79	83.99	90.0
Colorado:										
1904.	.....	44,456	550,359	12.38	124,553,800	62,277	11.32	15.64	82.46	87.1
1905.	.....	85,916	875,154	10.19	183,216,900	91,608	10.47	14.71	81.79	101.1
1906.	15	110,943	1,487,383	13.41	334,386,000	167,193	11.24	14.70	80.30	132.0
1907.	16	127,678	1,523,303	11.93	338,573,000	169,286	11.11	15.30	81.50	127.0
1908.	15	119,475	1,108,961	9.28	244,560,000	122,280	11.03	13.85	81.80	78.0
1909.	16	121,698	1,256,771	10.33	298,810,000	149,405	11.89	14.24	80.51	85.0
1910.	13	81,412	864,474	10.62	206,184,000	103,092	11.93	15.19	83.40	63.0
1911.	14	86,437	957,142	11.07	249,600,000	124,800	13.04	15.44	81.22	63.3
1912.	17	144,999	1,641,861	11.32	432,020,000	216,010	13.16	16.19	84.81	91.0
Michigan:										
1904.	.....	53,777	433,428	8.06	103,864,830	51,932	11.98	15.13	85.47	46.8
1905.	.....	77,823	531,475	6.83	132,917,999	66,459	12.50	15.65	84.67	58.9
1906.	16	98,984	805,309	8.57	177,214,000	88,607	11.00	14.50	83.20	85.0
1907.	16	88,334	696,785	7.89	169,452,000	84,726	12.16	15.10	84.70	70.0
1908.	16	81,073	611,295	7.54	170,598,000	85,299	13.95	17.11	84.80	61.0
1909.	16	112,232	819,923	7.31	212,106,000	106,053	12.93	17.00	86.21	74.0
1910.	17	117,500	1,207,700	10.28	278,430,000	139,215	11.53	16.08	86.15	100.0
1911.	17	145,837	1,443,856	9.90	251,000,000	125,500	8.69	14.59	59.55	122.0
1912.	16	124,241	838,784	6.75	190,098,000	95,049	11.33	14.72	83.75	74.0
Utah and Idaho:										
1904.	.....	27,750	318,500	11.48	74,315,900	37,158	11.67	14.82	83.24	77.5
1905.	.....	44,550	367,660	8.25	79,428,000	39,714	10.80	14.25	82.58	57.0
1906.	9	44,058	611,792	13.89	137,646,000	68,823	11.25	15.70	84.30	109.0
1907.	9	54,601	597,239	10.94	164,901,700	82,451	13.81	17.00	87.20	102.0
1908.	9	52,141	604,875	11.60	145,690,000	72,845	12.04	14.97	85.50	102.0
1909.	8	46,727	618,621	13.24	137,756,000	68,878	11.13	15.51	85.20	106.0
1910.	8	39,945	416,329	10.42	105,518,000	52,759	12.67	16.31	86.54	66.0
1911.	9	51,002	648,677	12.72	168,020,000	84,010	12.95	16.20	79.42	94.0
1912.	10	56,952	615,749	10.81	168,664,000	84,332	13.70	16.65	86.83	87.0
Wisconsin:										
1904.	.....	9,500	108,000	11.37	23,600,000	11,800	10.90	14.54	83.51	88.6
1905.	.....	14,000	124,000	8.86	28,487,029	14,244	11.49	15.00	83.00	85.0
1906.	4	15,560	158,600	10.19	35,220,000	17,610	11.10	13.60	83.00	83.0
1907.	4	11,837	122,800	10.37	30,320,000	15,160	12.35	15.10	85.60	61.0
1908.	4	14,700	137,800	9.37	36,640,000	18,320	13.30	16.72	84.50	71.0
1909.	4	14,000	143,000	10.21	34,340,000	17,170	12.01	15.88	85.17	63.0
1910.	4	16,772	153,327	9.14	36,260,000	18,130	11.82	16.75	84.14	76.0
1911.	4	23,241	256,124	11.02	47,280,000	23,640	9.23	14.23	64.86	106.0
1912.	4	20,172	207,085	10.27	46,520,000	23,260	11.23	15.10	84.31	90.0
Other States:										
1904.	.....	29,500	265,800	9.01	64,580,000	32,290	12.15	15.36	83.12	85.5
1905.	.....	33,218	253,233	7.62	54,004,400	27,002	10.66	14.04	81.10	85.2
1906.	11	51,388	501,457	9.76	97,278,000	48,639	9.70	14.00	80.90	111.0
1907.	10	41,147	342,928	8.33	77,964,230	38,982	11.37	15.10	82.30	70.0
1908.	10	35,222	304,875	8.65	74,500,000	37,250	12.22	15.22	82.00	54.0
1909.	11	42,605	360,983	8.47	87,382,000	43,691	12.10	15.09	83.21	61.0
1910.	11	51,900	482,362	9.29	114,172,000	57,086	11.83	15.66	82.69	68.0
1911.	12	67,815	719,251	10.61	160,500,000	80,250	11.16	15.16	73.60	83.0
1912.	15	97,520	916,570	9.40	230,002,000	115,001	12.55	15.70	83.18	86.0

¹ Percentage of sucrose (pure sugar) in the total soluble solids of the beets.

TABLE 6.—*Sugar-beet and beet-sugar production of the United States, 1901-1912, by principal States—Continued.*

State and year.	Facto- ries in opera- tion.	Sugar beets.			Sugar made. (Chiefly refined.)		Aver- age ex- traction of sugar based on weight of beets.	Aver- age sugar in beets	Aver- age purity coeffi- cient of beets. ¹	Aver- age length of cam- paign.
		Area har- vested.	Beets used for sugar	Aver- age per acre.						
United States:	No.	Acres.	Short tons.	Short tons.	Pounds.	Short tons.	Per cent	Per cent.	Per cent.	Days.
1901.....	36	175,083	1,685,689	9.63	369,211,733	184,606	10.95	14.80	82.20	88.0
1902.....	41	216,400	1,895,812	8.76	436,811,685	218,406	11.52	14.60	83.30	94.0
1903.....	49	242,576	2,076,494	8.56	481,209,087	240,604	11.59	15.10	.....	75.0
1904.....	48	197,784	2,071,539	10.47	484,226,430	242,113	11.69	15.33	83.10	78.0
1905.....	52	307,364	2,665,913	8.67	625,841,228	312,921	11.74	15.33	83.00	76.6
1906.....	63	376,074	4,236,112	11.26	967,224,000	483,612	11.42	14.90	82.20	105.0
1907.....	63	370,984	3,767,871	10.16	927,256,430	463,628	12.30	15.80	83.60	89.0
1908.....	62	364,913	3,414,891	9.36	851,768,000	425,884	12.47	15.74	83.50	74.0
1909.....	65	420,262	4,081,382	9.71	1,024,938,000	512,469	12.56	16.10	84.11	83.0
1910.....	61	398,029	4,047,292	10.17	1,020,344,000	510,172	12.61	16.35	84.35	83.0
1911.....	66	473,877	5,062,333	10.68	1,199,000,000	599,500	11.84	15.89	73.92	94.0
1912.....	73	555,300	5,224,377	9.41	1,385,112,000	692,556	13.26	16.31	84.49	86.0
Average:										
1901-1905.....	45	227,841	2,079,089	9.13	479,460,033	239,730	11.51	15.03	82.89	82.0
1906-1910.....	63	386,052	3,909,510	10.13	958,306,086	479,153	12.26	15.78	83.55	87.0

TABLE 7.—*Production and farm value of sugar beets in contiguous United States, 1899-1912, and in principal States, 1899, 1909, 1911, and 1912.*

[Except where otherwise stated, data refer to beets used in factories, as reported to the United States Department of Agriculture.]

State and year.	Produc- tion.	Aver- age farm price per ton.	Farm value.	State and year.	Produc- tion.	Aver- age farm price per ton.	Farm value.
California:	Short tons.	Dollars.	Dollars.	Other States:	Short tons.	Dollars.	Dollars.
1899 ¹	356,535	2 4.35	1,550,346	1899 ¹	128,875	2 3.91	503,539
1909 ¹	845,191	2 5.11	4,320,532	1909 ¹	554,708	2 5.07	2,812,713
1911.....	1,037,283	5 5.54	5,746,548	1911.....	975,375	5 5.47	5,332,869
1912.....	1,004,328	6 4.46	6,487,959	1912.....	1,123,655	5 5.61	6,299,469
Colorado:				United States:			
1899 ¹	6,656	2 4.01	26,711	1899 ¹	793,353	2 4.19	3,323,240
1909 ¹	1,231,712	2 4.92	6,061,152	1901.....	1,685,689	4 5.50	7,585,600
1911.....	957,142	5 5.55	5,312,138	1902.....	1,895,812	5 5.03	9,535,934
1912.....	1,641,861	5 5.96	9,785,492	1903.....	2,076,494	4 4.97	10,320,175
Michigan:				1904.....	2,071,539	3 4.95	10,254,118
1899 ¹	215,373	2 4.07	877,481	1905.....	2,665,913	3 5.00	13,329,565
1909 ¹	707,639	2 5.67	4,014,123	1906.....	4,236,112	3 5.10	21,604,171
1911.....	1,443,856	5 5.74	8,287,733	1907.....	3,767,871	3 5.20	19,592,929
1912.....	838,784	5 5.69	4,772,681	1908.....	3,414,891	3 5.35	18,269,667
Idaho and Utah:				1909 ¹	3,932,857	2 5.06	19,880,724
1899 ¹	85,914	2 4.25	365,163	1910.....	4,047,292	.....	.....
1909 ¹	593,607	2 4.50	2,672,204	1911.....	5,062,333	5 5.50	27,842,832
1911.....	648,677	4 4.88	3,163,544	1912.....	5,224,377	5 5.82	30,405,874
1912.....	615,749	4 4.97	3,060,273				

¹ Total beets produced. From United States Census of Agriculture.² Computed by dividing total tons produced into total farm value.³ Senate Document 22; Sixty-first Congress, first session.

TABLE 8.—*Sugar-cane area and production in the United States, 1909, by principal States and counties.*

[Census.]

State and county.	Area.	Production.	Average yield per acre.	State and county.	Area.	Production.	Average yield per acre.
	Acres.	Short tons.	Short tons.		Acres.	Short tons.	Short tons.
Alabama:				Georgia—Contd.			
Barbour.....	953	7,815	8.2	Liberty.....	1,295	7,822	6.0
Bullock.....	627	5,211	8.3	Montgomery.....	757	9,367	12.4
Butler.....	747	7,194	9.6	Pierce.....	535	5,087	9.5
Chambers.....	914	7,865	8.6	Screven.....	572	6,917	12.1
Chilton.....	548	4,648	8.5	Thomas.....	1,259	21,938	17.4
Choctaw.....	520	4,462	8.6	Upson.....	716	5,141	7.2
Clarke.....	768	6,180	8.0	Washington.....	1,194	7,396	6.2
Coffee.....	938	7,402	7.9	Wilcox.....	574	3,891	6.8
Conecuh.....	600	4,737	7.9	Worth.....	514	4,412	8.6
Covington.....	786	7,250	9.2	Other counties.	16,873	135,615	8.0
Crenshaw.....	674	5,405	8.0				
Dale.....	840	7,489	8.9	Total.....	37,046	317,460	8.6
Elmore.....	620	5,116	8.3				
Geneva.....	1,012	11,259	11.1	Louisiana:			
Henry.....	658	9,064	13.8	Ascension.....	9,628	137,674	14.3
Houston.....	1,004	12,007	12.0	Assumption.....	27,852	491,743	17.7
Lee.....	523	5,077	9.7	Avoyelles.....	7,335	128,155	17.5
Monroe.....	699	6,743	9.6	East Baton Rouge.....	2,107	38,068	18.1
Montgomery.....	619	4,465	7.2	Iberia.....	36,585	433,778	11.9
Perry.....	676	4,982	7.4	Iberville.....	20,764	359,369	17.3
Pike.....	668	5,359	8.0	Jefferson.....	2,104	31,101	14.8
Russell.....	588	4,296	7.3	Lafayette.....	12,218	171,059	14.0
Sumter.....	543	3,055	5.6	Lafourche.....	33,200	562,538	16.9
Tallapoosa.....	514	6,541	12.7	Orleans.....	1,653	27,057	16.4
Wilcox.....	1,269	9,578	7.5	Plaquemines.....	6,643	108,996	16.4
Other counties.	8,903	63,434	7.1	Pointe Coupee.....	3,806	72,435	19.0
Total.....	27,211	226,634	8.3	Rapides.....	7,452	127,670	17.1
				St. Bernard.....	2,335	25,090	10.7
Arkansas:				St. Charles.....	6,757	110,871	16.4
Ashley.....	392	3,023	7.7	St. James.....	20,526	312,001	15.2
Clark.....	296	1,170	4.0	St. John the Baptist.....	12,669	232,268	18.3
Columbia.....	359	2,110	5.9	St. Landry.....	6,423	94,050	14.6
Drew.....	269	1,779	6.6	St. Martin.....	11,365	144,799	12.7
Howard.....	226	969	4.3	St. Mary.....	42,324	504,010	11.9
Sevier.....	203	1,277	6.3	Terrebonne.....	23,797	435,615	18.3
Union.....	637	4,768	7.5	Vermilion.....	7,637	86,664	11.3
Other counties.	948	4,772	5.0	West Baton Rouge.....	10,271	176,800	17.2
Total.....	3,330	19,868	6.0	Other parishes.	14,233	130,185	9.1
				Total.....	329,684	4,941,996	15.0
Florida:							
Alachua.....	577	6,143	10.6	Mississippi:			
Gadsden.....	935	12,053	12.9	Amite.....	843	10,711	12.7
Hillsboro.....	589	8,163	13.9	Attala.....	755	6,250	8.3
Jackson.....	1,049	9,798	9.3	Clarke.....	625	5,281	8.4
Jefferson.....	609	3,995	6.6	Copiah.....	943	7,907	8.4
Leon.....	564	5,096	9.0	Hinds.....	1,166	8,046	6.9
Madison.....	660	7,108	10.8	Holmes.....	755	7,292	9.7
Marion.....	551	2,448	4.4	Jasper.....	635	5,779	9.1
Suwannee.....	826	11,106	13.4	Jefferson Davis.....	515	7,446	14.5
Other counties.	6,568	76,607	11.7	Jones.....	1,010	7,075	7.0
Total.....	12,928	142,517	11.0	Kemper.....	577	5,273	9.1
				Lafayette.....	563	1,791	3.2
Georgia:				Lauderdale.....	643	6,433	10.0
Berrien.....	907	7,924	8.7	Lawrence.....	515	7,896	15.3
Brooks.....	898	10,025	11.2	Leake.....	554	4,545	8.2
Bullock.....	1,842	15,245	8.3	Lincoln.....	1,045	9,118	8.7
Burke.....	578	3,970	6.9	Neshoba.....	521	3,751	7.2
Coffee.....	560	4,312	7.7	Newton.....	584	5,696	9.8
Colquitt.....	708	5,589	7.9	Pike.....	1,111	13,406	12.1
Decatur.....	1,194	13,138	11.0	Rankin.....	564	4,685	8.3
Effingham.....	592	4,050	6.8	Simpson.....	689	4,884	7.1
Emanuel.....	1,073	5,324	5.0	Other counties.	10,248	89,335	8.7
Grady.....	2,181	21,514	9.9				
Jefferson.....	817	5,297	6.5	Total.....	24,861	222,600	9.0
Johnson.....	590	3,725	6.3				
Laurens.....	817	9,761	11.9				

TABLE 8.—*Sugar-cane area and production in the United States, 1909, by principal States and counties—Continued.*

State and county.	Area.	Production.	Average yield per acre.	State and county.	Area.	Production.	Average yield per acre.
	<i>Acres.</i>	<i>Short tons.</i>	<i>Short tons.</i>		<i>Acres.</i>	<i>Short tons.</i>	<i>Short tons.</i>
North Carolina:				Texas—Contd.			
Brunswick.....	5	40	8.0	Cass.....	567	4,433	7.8
Columbus.....	91	648	7.1	Colorado.....	1,324	12,803	9.7
Pender.....	75	238	3.2	Fayette.....	579	1,391	2.4
Robeson.....	123	568	4.6	Fort Bend.....	6,775	90,827	13.4
Total.....	294	1,494	5.1	Guadalupe.....	573	1,071	1.9
South Carolina:				Nacogdoches.....	612	3,765	6.2
Bamberg.....	398	3,519	8.8	Rusk.....	892	5,589	6.3
Barnwell.....	545	6,348	11.6	Shelby.....	956	4,748	5.0
Clarendon.....	329	1,972	6.0	Smith.....	605	3,231	5.3
Colleton.....	495	3,502	7.1	Wharton.....	4,714	36,434	7.7
Hampton.....	682	6,820	10.0	Wood.....	518	5,985	11.6
Orangeburg.....	1,107	12,531	11.3	Other counties.....	12,559	76,486	6.1
Other counties.....	3,497	25,173	7.2	Total.....	34,315	307,502	9.0
Total.....	7,053	59,865	8.5	Other States.....	127	324	2.6
Texas:				United States	476,849	6,240,260	13.1
Brazoria.....	2,037	26,288	12.9				
Cameron.....	1,604	34,451	21.5				

TABLE 9.—*Production of cane sirup and cane molasses in the United States, 1899-1909, by principal States.¹*

[By "sirup" is meant the liquid cane product from which no sugar has been extracted; by "molasses" is meant the liquid cane product from which more or less sugar has been extracted.]

State.	1899	1909	State.	1899.	1909
	Farm and factory production.	Farm production. ²		Farm and factory production.	Farm production. ²
<i>Sirup.</i>			<i>Molasses.</i>		
	<i>Gallons.</i>	<i>Gallons.</i>		<i>Gallons.</i>	<i>Gallons.</i>
Georgia.....	3,226,367	5,533,520	All States.....		4,153
Louisiana.....	2,480,856	4,125,083	Louisiana.....	11,703,877	² 24,342,555
Alabama.....	2,672,438	3,078,531	Texas.....	98,950	³ 425,810
Mississippi.....	1,413,219	2,920,519	Total molasses.....	11,802,827	24,772,518
Florida.....	1,687,452	2,533,096	Total sirup and molasses.....	25,024,074	47,855,957
Texas.....	888,637	2,246,774			
South Carolina.....	805,064	881,558			
Arkansas.....	44,819	286,637			
North Carolina.....	1,957	21,677			
Other States.....	438	6,184			
Louisiana.....		³ 942,997			
Other States.....		³ 506,863			
Total sirup.....	13,221,247	23,083,439			

¹ Census.² Farm production except as noted.³ Factory production.

TABLE 10.—*Production of cane sugar in Louisiana, 1849–1912, by principal parishes.*¹

[Chiefly raw sugar.]

Parish.	1849	1859	1869	1879	1889	1898	1899	1910	1911	1912
	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
Ascension.....	6,719	8,044	3,212	6,714	13,569	16,386	6,004	13,529	14,496	8,342
Assumption.....	8,580	8,854	4,779	5,966	16,859	26,162	13,523	31,907	35,950	14,457
Iberia.....	.....	.....	927	3,200	5,991	17,404	11,125	33,383	29,949	10,999
Iberville.....	11,604	5,414	2,454	7,636	15,533	17,693	7,305	28,246	23,759	7,942
Lafourche.....	5,028	7,368	3,564	5,592	10,826	28,345	19,391	42,639	42,001	11,728
St. James.....	10,835	6,868	3,132	7,125	10,539	21,644	10,939	21,687	20,760	9,368
St. John the Baptist.....	5,968	2,490	2,481	4,507	6,285	12,972	8,231	13,206	14,935	11,289
St. Martin.....	2,094	3,750	747	1,626	2,141	5,574	3,077	10,377	13,719	5,382
St. Mary.....	12,382	15,366	3,296	8,268	17,018	52,384	26,659	54,397	57,602	25,597
Terrebonne.....	4,586	8,511	3,268	6,876	11,490	25,144	19,981	30,392	27,462	14,463
West Baton Rouge.....	3,960	5,088	403	3,162	10,136	12,893	3,883	15,164	17,235	9,328
Avoyelles, Rapides, and St. Landry.....	7,522	9,984	2,818	3,042	4,832	5,983	1,833	3,848	3,558	2,423
East Baton Rouge, Pointe Coupee, and West Feliciana.....	7,817	8,832	1,191	4,150	4,402	5,950	1,596	5,229	9,928	2,237
Jefferson, Orleans, Plaquemines, and St. Charles.....	18,716	15,596	7,292	14,907	13,739	24,244	18,789	19,714	18,040	5,471
Lafayette and Vermilion.....	1,750	1,276	194	963	1,641	4,663	5,895	18,277	23,480	14,547
Other parishes.....	5,439	3,422	595	1,819	1,061	1,056	1,352	.....	.....	.....
Total.....	113,000	110,863	40,353	85,853	146,062	278,497	159,583	341,995	352,874	153,573

¹ Data for 1911 and 1912 from Bureau of Statistics, United States Department of Agriculture; 1910 from Louisiana Sugar Planters' Association; other years from Census. Census data refer to parishes in which the cane was grown; other data (1910–1912) refer to parishes in which the sugar was made.

TABLE 11.—*Sugar made, factories operated, and cane used for sugar in Louisiana, 1911 and 1912, by principal parishes.*

Parish.	Factories in operation.		Average days in operation. ¹	Sugar made (chiefly raw).				Cane used for sugar. ¹	
				Quantity.		Average per short ton of cane. ¹			
	1911	1912	1912 ²	1911	1912	1911	1912	1911	1912
	No.	No.	Days.	Short tons.	Short tons.	Pounds.	Pounds.	Short tons.	Short tons.
Ascension.....	7	7	29	14,496	8,342	124	134	234,719	124,934
Assumption.....	23	16	29	35,950	14,457	107	119	673,263	243,864
Iberia.....	13	9	27	29,949	10,999	129	156	464,491	140,932
Iberville.....	18	11	26	23,759	7,942	99	112	481,545	141,581
Lafourche.....	16	9	23	42,001	11,728	119	122	707,764	191,714
St. James.....	20	10	32	20,760	9,368	115	97	361,537	192,537
St. John the Baptist.....	8	5	42	14,935	11,289	108	140	275,536	161,790
St. Martin.....	4	3	31	13,719	5,382	139	173	197,614	62,165
St. Mary.....	26	15	34	57,602	25,597	133	176	866,744	291,387
Terrebonne.....	14	14	28	27,462	14,463	124	150	442,218	191,984
West Baton Rouge.....	10	10	26	17,235	9,328	110	147	314,472	127,196
Avoyelles, Rapides, and St. Landry....	5	5	35	3,558	2,423	101	136	70,534	35,629
East Baton Rouge, Pointe Coupee, and West Feliciana.....	6	3	36	9,928	2,237	116	187	171,763	23,916
Jefferson, Orleans, Plaquemines, and St. Charles.....	13	3	37	18,040	5,471	125	160	288,665	68,365
Lafayette and Vermilion.....	5	6	33	23,480	14,547	140	177	336,427	164,580
Louisiana.....	188	126	30	352,874	153,573	120	142	5,887,292	2,162,574

¹ Computed from incomplete returns.

² This campaign was unusually short, owing to the small crop. In 1911 the average time from beginning to end of campaign was 74 days for the entire State.

TABLE 12.—*Area of sugar cane, of other principal crops, and of total improved farm land in Louisiana, 1909, by principal sugar-producing parishes.*

[Census.]

Parish.	Acreage of 5 principal crops.						Improved land in farms.
	Sugar cane.	Cotton.	Rice.	Corn.	Hay and forage.	Total 5 crops.	
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
Ascension.....	9,628	7,277	4,867	17,730	2,050	41,552	57,119
Assumption.....	27,852	244	.....	19,888	7,542	55,526	54,069
Avoyelles.....	7,335	26,634	1,810	58,847	2,946	97,572	126,440
East Baton Rouge.....	2,107	23,812	565	26,701	5,617	58,802	103,481
Iberia.....	36,585	3,252	3,912	44,476	5,267	93,492	121,436
Iberville.....	20,764	1,839	4,559	20,203	5,275	52,640	64,422
Jefferson.....	2,104	.....	1,075	1,595	962	5,736	14,196
Lafayette.....	12,218	19,929	2,508	67,317	4,830	106,802	141,762
Lafourche.....	33,200	.....	1,402	28,479	10,902	73,983	86,281
Orleans.....	1,653	.....	.....	762	73	2,488	5,187
Plaquemines.....	6,643	.....	7,222	2,774	1,039	17,678	30,397
Pointe Coupee.....	3,806	18,164	4,176	53,071	7,342	86,559	115,829
Rapides.....	7,452	15,420	22	39,526	8,797	71,217	108,742
St. Bernard.....	2,335	.....	725	941	1,913	5,914	9,882
St. Charles.....	6,757	4	4,287	4,874	562	16,484	21,250
St. James.....	20,526	99	4,551	12,150	7,315	44,641	48,755
St. John the Baptist.....	12,669	.....	4,655	6,534	2,979	26,837	29,438
St. Landry.....	6,423	55,169	21,592	126,257	2,903	212,344	327,623
St. Martin.....	11,365	14,699	581	37,900	2,504	67,049	87,320
St. Mary.....	42,324	6	400	27,436	17,454	87,620	102,938
Terrebonne ¹	23,797	.....	38	15,745	10,168	49,748	49,428
Vermilion.....	7,637	15,733	29,595	53,075	1,696	107,736	177,824
West Baton Rouge.....	10,271	3,350	3,397	13,515	2,087	32,620	39,866
Total, 23 parishes.....	315,451	205,631	101,939	679,796	112,223	1,415,040	1,923,685
All other parishes.....	14,233	751,380	215,579	911,034	68,588	1,960,814	3,352,331
Total, Louisiana.....	329,684	957,011	317,518	1,590,830	180,811	3,375,854	5,276,016

¹For this parish the census shows 320 less acres in "improved land" than in the 5 principal crops—apparently an error.

TABLE 13.—*Percentage of cane acreage in Louisiana reserved for seed, 1909, 1910, and 1911.¹*

Year.	Number of plantations reporting.	Total area.	Saved for seed.	
			Area.	Per cent of total.
	<i>Number.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Per cent.</i>
1909.....	28	14,832	3,641	24.5
1910.....	38	18,037	3,651	20.2
1911.....	56	32,075	6,519	20.3
Mean.....	.....	.....	.....	21.7

¹ Computed from report on The Sugar Industry, by F. J. Sheridan, Department of Commerce (Miscellaneous series No. 9) p. 2.

TABLE 14.—*Proportion of acreage of plant cane to other cane and average yield per acre of cane used for sugar in Louisiana and Hawaii, 1911 and 1912.*

[In Louisiana each planting of cane is generally allowed to bear two annual crops, while in Hawaii three annual crops are generally cut from each planting. The figures in this table refer only to cane used for sugar, thus excluding cane reserved for planting and that used for sirup.]

Item.	Plant cane (1st cutting).		Stubble or ratoon cane (2d and later cuttings). ¹		Total.	Average yield of cane per acre.
	Quantity.	Per cent of total.	Quantity.	Per cent of total.		
Louisiana:	<i>Acres.</i>	<i>Per cent.</i>	<i>Acres.</i>	<i>Per cent.</i>	<i>Acres.</i>	<i>Short tons.</i>
1911.....	168,000	54	146,000	46	314,000	18.7
1912.....	118,000	58	87,000	42	205,000	10.5
Hawaii:						
1910-11.....	43,900	38	73,100	62	117,000	41.3
1911-12.....	37,200	33	75,800	67	113,000	42.3

¹ The term "stubble" is used in Louisiana and "ratoon" in Hawaii to refer to the second or later crops grown from the same planting from which a first crop ("plant" cane) has been harvested.

TABLE 15.—*Seasonal receipts at New Orleans of Louisiana sugar, 1901-2 to 1912-13.*¹

Year.	From Sept. 1 to last Friday in—								Year, Sept. 1 to Aug. 31.
	October.		November.		December.		March.		
	Quantity.	Per cent of year's receipts.	Quantity.	Per cent of year's receipts.	Quantity.	Per cent of year's receipts.	Quantity.	Per cent of year's receipts.	
	Short tons.	Per cent.	Short tons.	Per cent.	Short tons.	Per cent.	Short tons.	Per cent.	Short tons.
1901-2.....	13,367	4.5	88,938	30.2	173,571	58.8	267,092	90.6	² 294,941
1902-3.....	9,672	3.4	81,608	28.6	191,558	67.2	253,986	89.1	³ 285,031
1903-4.....	5,159	2.7	60,138	31.8	155,045	81.9	175,991	93.0	189,330
1904-5.....	8,579	2.6	80,764	24.5	197,847	60.1'	281,744	85.5	329,339
1905-6.....	9,481	3.0	94,134	29.6	189,472	59.6	283,510	89.2	317,868
1906-7.....	2,367	1.4	52,723	30.2	121,533	69.6	161,239	92.4	174,561
1907-8.....	2,010	.7	86,661	28.8	198,407	65.9	275,195	91.4	301,158
1908-9.....	11,062	3.9	111,060	39.3	221,286	78.2	252,899	89.4	282,800
1909-10.....	8,275	3.1	96,350	36.4	215,349	81.4	247,521	93.6	264,560
1910-11.....	2,893	1.1	81,076	29.9	225,584	83.3	265,782	98.1	270,865
1911-12.....	16,703	5.9	105,968	37.5	192,630	68.1	258,418	91.4	282,815
1912-13.....	9,085	7.2	69,707	55.0	115,930	91.5	120,230	94.9	126,706
Average:									
1901-2 to 1905-6.....	9,252	3.3	81,116	28.6	181,499	64.1	252,465	89.1	283,302
1906-7 to 1910-11.....	5,321	2.1	85,574	33.1	196,432	75.9	240,527	92.9	258,789

¹ Compiled from Willett & Gray's Weekly Statistical Sugar Trade Journal.

² To Aug. 29.

³ To Aug. 26.

TABLE 16.—Average cost of producing cane sugar in Louisiana, 1909, 1910, and 1911.¹

Item.	Per ton of cane used.			Per pound of sugar made.		
	1909	1910	1911	1909	1910	1911
COST OF PRODUCING CANE.						
Planting and cultivating.....	\$0.500	\$0.740	\$0.774	-----	-----	-----
Harvesting.....	.739	.757	.799	-----	-----	-----
Other, including repairs, maintenance, supplies, taxes, insurance, etc. ²	2.911	2.810	2.428	-----	-----	-----
Total.....	4.150	4.307	4.001	-----	-----	-----
COST OF MAKING SUGAR.						
Cost of cane delivered at factory.....	4.182	4.090	4.530	\$0.0267	\$0.0277	0.0340
Manufacturing labor.....	.331	.324	.340	.0021	.0022	.0025
Repairs and maintenance.....	.334	.371	.341	.0022	.0025	.0025
Other operating expenses, including supplies, taxes, insurance, office expenses, etc.....	.811	.713	.635	.0052	.0048	.0049
Total.....	5.658	5.498	5.846	.0362	.0372	.0439
Cost of selling sugar.....	.288	.246	.226	.0018	.0017	.0016
Total cost of manufacture and sale..	5.946	5.744	6.072	.0380	.0389	.0455
Gross receipts from sale of sugar.....	6.856	6.198	6.462	.0438	.0420	.0485

¹ From report on The Sugar Industry, by F. J. Sheridan, Department of Commerce (Miscellaneous series No. 9), pp. 3 and 72.

² Excluding interest and depreciation.

TABLE 17.—Monthly prices of sugar per pound at New York and New Orleans, 1909-1912.¹

FINE AND STANDARD GRANULATED, AT NEW YORK, N. Y.

Month.	1909		1910		1911		1912	
	Low.	High.	Low.	High.	Low.	High.	Low.	High.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
January.....	4.65	4.65	4.95	5.15	4.70	4.80	5.40	5.80
February.....	4.55	4.65	5.15	5.25	4.60	4.70	5.40	5.85
March.....	4.65	4.95	5.25	5.25	4.70	4.80	5.50	5.85
April.....	4.95	5.05	5.15	5.25	4.80	4.90	5.10	5.55
May.....	4.95	5.05	5.15	5.25	4.90	4.90	5.10	5.25
June.....	4.95	4.95	5.15	5.25	4.90	5.00	5.00	5.25
July.....	4.85	4.95	5.15	5.15	5.00	5.65	5.00	5.15
August.....	4.95	5.05	5.15	5.25	5.65	6.20	5.00	5.15
September.....	5.05	5.30	5.05	5.25	6.25	6.80	5.10	5.15
October.....	5.15	5.15	4.65	5.05	6.65	6.80	4.90	5.15
November.....	5.15	5.25	4.60	4.65	6.15	6.65	4.95	4.95
December.....	4.95	5.25	4.90	4.90	5.80	6.05	4.95	4.95
The year.....	4.55	5.30	4.60	5.25	4.60	6.80	4.90	5.85

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January.....	3.67	3.75	4.02	4.18	3.42	3.86	4.39	4.65
February.....	3.61	3.74	4.08	4.36	3.45	3.80	4.39	4.80
March.....	3.74	4.00	4.36	4.42	3.67	3.92	4.36	4.67
April.....	3.86	4.05	4.24	4.36	3.86	3.92	3.98	4.36
May.....	3.86	3.95	4.24	4.33	3.80	3.86	3.86	4.05
June.....	3.86	3.92	4.17	4.30	3.83	3.98	3.83	3.98
July.....	3.92	4.02	4.30	4.36	3.98	4.70	3.77	4.05
August.....	4.02	4.11	4.30	4.48	4.61	5.36	3.98	4.24
September.....	4.11	4.24	4.05	4.42	5.25	5.96	4.17	4.36
October.....	4.20	4.40	3.80	4.00	5.74	5.96	4.05	4.17
November.....	4.30	4.45	3.80	3.93	5.06	5.74	4.05	4.05
December.....	4.02	4.33	3.93	4.05	4.61	5.06	3.73	4.05
The year.....	3.61	4.45	3.80	4.48	3.42	5.96	3.73	4.80

¹ New York prices from Yearbook of United States Department of Agriculture; New Orleans prices from the Louisiana Planter.

TABLE 17.—*Monthly prices of sugar per pound at New York and New Orleans, 1909-1912—Continued.*

STANDARD FINE GRANULATED, AT NEW ORLEANS, LA.

Month.	1909		1910		1911		1912	
	Low.	High.	Low.	High.	Low.	High.	Low.	High.
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
January.....	4.60	4.60	4.90	5.10	4.60	4.80	5.40	5.75
February.....	4.50	4.60	5.10	5.20	4.60	4.70	5.40	5.90
March.....	4.50	5.00	5.20	5.25	4.70	4.80	5.50	5.80
April.....	4.90	5.00	5.15	5.15	4.80	4.90	5.20	5.50
May.....	4.90	5.00	5.15	5.25	4.90	5.00	5.10	5.20
June.....	4.80	4.90	5.15	5.15	5.00	5.00	5.00	5.20
July.....	4.80	4.90	5.15	5.15	5.00	5.45	5.00	5.10
August.....	4.90	5.00	5.15	5.25	5.15	6.35	5.00	5.20
September.....	5.00	5.10	5.05	5.25	6.35	6.80	5.00	5.20
October.....	5.10	5.10	4.65	5.05	6.70	6.80	4.90	5.00
November.....	5.10	5.20	4.60	4.60	6.20	6.70	4.90	4.90
December.....	4.90	5.20	4.80	4.80	5.75	6.20	4.90	4.90
The year.....	4.50	5.20	4.60	5.25	4.60	6.80	4.90	5.90

OF 96° POLARIZATION, AT NEW ORLEANS, LA.

January.....	3.62	3.69	3.88	4.09	3.18	3.71	4.36	4.48
February.....	3.61	3.69					4.36	4.36
March.....	3.61	4.00						
April.....								
May.....								
June.....	3.92	3.92						
July.....	3.07	3.98						
August.....	3.00	4.17						
September.....	4.17	4.24						
October.....	4.06	4.24						
November.....	4.00	4.12	3.62	3.69	4.78	4.83	3.80	3.84
December.....	3.88	4.09	3.65	3.81	4.57	4.81	3.75	3.87
The year.....	3.00	4.24	3.62	4.09	3.18	4.83	3.75	4.48

PRIME YELLOW CLARIFIED, AT NEW ORLEANS, LA.

January.....	3.81	4.12	4.25	4.56	3.88	4.12	4.09	5.19
February.....	3.94	4.09	4.44	4.56	4.03	4.38	4.81	5.59
March.....	3.94	4.12	4.44	4.78	4.25	4.50	5.12	5.56
April.....	4.06	4.69	4.69	4.78	4.38	4.53	4.81	5.31
May.....	4.06	4.25	4.69	4.97	4.38	4.53	4.69	5.81
June.....	4.00	4.22	4.81	4.97	4.44	4.69	4.62	4.81
July.....	4.00	4.19	4.81	4.94	4.56	5.12	4.50	4.72
August.....	4.03	4.25	4.88	5.00	5.00	5.31	4.12	4.69
September.....	4.12	4.25	5.00	5.00			4.00	4.50
October.....	4.12	4.44	4.19	5.00	5.75	6.25	3.94	4.44
November.....	4.19	4.38	3.78	4.28	4.88	5.34	4.00	4.22
December.....	4.25	4.41	3.84	4.06	4.97	5.16	4.03	4.31
The year.....	3.81	4.69	3.78	5.00	3.88	6.25	3.94	5.81

TABLE 18.—*Railroad freight rates, per 100 pounds, on refined sugar carried in carloads, over selected routes in the United States, May, 1913.*¹

From—	To—					
	Chicago, Ill.		Omaha, Nebr.		Atlanta, Ga.	
	Rate per 100 pounds.	Minimum weight of carload.	Rate per 100 pounds.	Minimum weight of carload.	Rate per 100 pounds.	Minimum weight of carload.
Bay City, Mich.	<i>Cents.</i> 11	<i>Pounds.</i> 33,000	<i>Cents.</i> 38	<i>Pounds.</i> 2 33,000	<i>Cents.</i> 65	<i>Pounds.</i> 3 33,000
Colorado sugar-factory points (Longmont, Fort Morgan, Brush, Greeley, etc.).....	{ 35	33,000	{ 25	33,000	58	4 33,000
New Orleans, La.	{ 25	60,000	{ 32	33,000	23	24,000
New York, N. Y.	{ 23	33,000	{ 40	33,000	39	24,000
Salt Lake City, Utah.....	{ 26	33,000	{ 55	33,000	86	4 33,000
San Francisco, Cal.	{ 60	33,000	{ 50	60,000	81	4 60,000
	{ 65	36,000	{ 60	36,000	88	4 36,000
	{ 60	60,000	{ 55	60,000	83	4 60,000

¹ Data furnished by the Bureau of Tariffs, Interstate Commerce Commission.² Minimum weight, Mississippi River to Omaha, 36,000 pounds.³ Minimum weight, Cincinnati to Atlanta, 24,000 pounds.⁴ Minimum weight, Memphis to Atlanta, 24,000 pounds.TABLE 19.—*Sugar imported into the United States from foreign countries and received from Hawaii and Porto Rico, 1901-1912.*¹

[In the statistics of the foreign trade of the United States the Philippine Islands are treated as a foreign country; all other noncontiguous possessions as parts of the United States. Most of the imported sugar is raw.]

Country or possession from which consigned.	Year ending June 30—			
	1901-1905	1906-1910	1911	1912
	Average per year.			
IMPORTS.	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
Cuba.....	935,736	1,469,948	1,673,803	1,593,317
Philippine Islands.....	17,446	39,246	115,176	217,785
Dutch East Indies.....	364,622	305,196	114,039	170,198
British Guiana.....	66,624	15,056	7,051	13,527
Brazil.....	78,144	11,552	344	13,482
Danish West Indies.....	11,015	9,029	1,157	9,022
Santo Domingo.....	53,666	33,427	12,291	8,841
Peru.....	41,749	13,019	4,569	6,579
Dutch Guiana.....	6,505	5,813	3,231	4,266
Austria-Hungary.....	32,014	3,674	1,000	3,751
United Kingdom.....	3,006	4,129	19,007	2,930
Canada.....	1,631	1,135	587	2,877
British West Indies.....	76,629	9,796	53	2,781
Mexico.....	2,941	4,355	121	1,256
China.....	2,401	414	406	574
Guatemala.....	1,691	1,157	911	441
Germany.....	123,701	67,100	12,622	285
Hongkong.....	646	199	247	179
Venezuela.....	37	169	327	135
Other countries.....	40,255	8,300	2,047	83
Total imports.....	1,860,459	2,002,714	1,968,989	2,052,309
SHIPMENTS TO THE UNITED STATES FROM—				
Hawaii.....	375,547	477,965	505,608	602,733
Porto Rico.....	107,771	234,539	322,917	367,145
Total, Hawaii and Porto Rico.....	483,318	712,504	828,525	969,878
Grand total.....	2,343,777	2,715,218	2,797,514	3,022,187

¹ Compiled from reports of the Foreign Commerce and Navigation of the United States, Bureau of Foreign and Domestic Commerce, Department of Commerce.

TABLE 20.—*Percentage from each country of consignment of sugar imported into the United States, 1901-1912.*¹

[In the statistics of the foreign trade of the United States, the Philippine Islands are treated as a foreign country; all other noncontiguous possessions, as parts of the United States. Most of the imported sugar is raw.]

Country from which consigned.	Year ending June 30—			
	1901-1905	1906-1910	1911	1912
	Average per year.			
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cuba.....	50.3	73.4	85.0	77.6
Philippine Islands.....	.9	2.0	5.8	10.6
Dutch East Indies.....	19.6	15.2	5.8	8.3
British Guiana.....	3.6	.8	.4	.7
Brazil.....	4.2	.6	(²)	.7
Danish West Indies.....	.6	.5	.1	.4
Santo Domingo.....	2.9	1.7	.6	.4
Peru.....	2.2	.7	.2	.3
Dutch Guiana.....	.3	.3	.2	.2
Austria-Hungary.....	1.7	.2	.1	.2
United Kingdom.....	.2	.2	1.0	.1
Canada.....	.1	.1		.1
British West Indies.....	4.1	.5		.1
Mexico.....	.2	.2	.1	.1
China.....	.1	(²)		
Guatemala.....	.1	.1		
Germany.....	6.6	3.3	.6	
Hongkong.....	(²)	(²)	(²)	.2
Venezuela.....	(²)	(²)	(²)	
Other countries.....	2.3	.2	.1	
Total.....	100.0	100.0	100.0	100.0

¹ Compiled from reports of the Foreign Commerce and Navigation of the United States, Bureau of Foreign and Domestic Commerce, Department of Commerce.

² Less than 0.05 of 1 per cent.

TABLE 21.—*Comparison of raw and refined sugar in the imports into the United States, 1881-1912.*¹

[Not including receipts into the United States from Hawaii and Porto Rico subsequent to 1900. In the statistics of the foreign trade of the United States, the Philippine Islands are treated as a foreign country; Hawaii and Porto Rico since 1900, and Alaska for the entire period covered below, as part of the United States.]

Kind.	Year ending June 30—							
	1881-1885	1886-1890	1891-1895	1896-1900	1901-1905	1906-1910	1911	1912
	Average per year.							
	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>
Raw.....	1,154,780	1,422,221	1,855,632	1,894,161	1,831,131	1,999,146	1,966,888	2,049,317
Refined.....	164	61	16,982	56,189	29,328	3,568	2,101	2,992
Total.....	1,154,944	1,422,282	1,872,614	1,950,350	1,860,459	2,002,714	1,968,989	2,052,309
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Raw.....	100.0	100.0	99.1	97.1	98.4	99.8	99.9	99.9
Refined.....	(²)	(²)	.9	2.9	1.6	.2	.1	.1
Total.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

¹ Compiled from annual reports of the Foreign Commerce and Navigation of United States, Bureau of Foreign and Domestic Commerce, Department of Commerce.

² Less than 0.05 of 1 per cent.

TABLE 22.—Imports of sugar into the United States, 1881-1912, by principal customs districts.¹

[In the statistics of the foreign trade of the United States, the Philippine Islands are treated as a foreign country; Hawaii and Porto Rico since 1900, and Alaska for the entire period covered below, as part of the United States. Most of the imported sugar is raw.]

Custom district.	Year ending June 30—							1911	1912
	1881-1885	1886-1890	1891-1895	1896-1900	1901-1905	1906-1910			
	Average per year.								
	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	<i>Short tons</i>	
New York, N. Y.	749,022	839,093	903,577	1,140,794	1,223,355	1,426,388	1,311,829	1,385,715	
Philadelphia, Pa.	90,492	237,612	513,737	385,854	280,811	223,276	236,879	210,327	
Boston and Charles- town, Mass.	215,165	187,445	200,466	189,986	181,974	184,449	169,586	190,879	
New Orleans, La.	12,434	17,293	70,651	68,634	154,585	145,614	211,379	209,033	
San Francisco, Cal.	68,054	129,619	163,935	146,040	10,282	19,470	32,879	30,866	
Other ports.	19,777	11,220	20,248	19,042	9,452	3,517	6,437	25,489	
Total.	1,154,944	1,422,282	1,872,614	1,950,350	1,860,459	2,002,714	1,968,989	2,052,309	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
New York, N. Y.	64.9	59.0	48.3	58.5	65.8	71.2	66.6	67.5	
Philadelphia, Pa.	7.8	16.7	27.4	19.8	15.1	11.2	12.0	10.2	
Boston and Charles- town, Mass.	18.6	13.2	10.7	9.7	9.8	9.2	8.6	9.3	
New Orleans, La.	1.1	1.2	3.8	3.5	8.3	7.3	10.7	10.2	
San Francisco, Cal.	5.9	9.1	8.8	7.5	.6	1.0	1.7	1.5	
Other ports.	1.7	.8	1.0	1.0	.4	.1	.4	1.3	
Total.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	

¹ Compiled from the annual reports of the Foreign Commerce and Navigation of the United States, Bureau of Foreign and Domestic Commerce, Department of Commerce. Data for 1901-1905 and subsequently are not strictly comparable with data for earlier years, because receipts from Hawaii and Porto Rico, subsequent to 1900, have been omitted from foreign trade, and the sugar received from those possessions in 1901-1905 and subsequently is not represented in the above table.

TABLE 23.—Production of sugar and shipments to the United States, for Hawaii and Porto Rico, 1901-2 to 1912-13.¹

[Chiefly raw.]

Year.	Hawaii (year ending Sept. 30).			Porto Rico (year ending June 30).		
	Production.	Shipped to the United States.		Production.	Shipped to the United States.	
		Quantity.	Per cent of production.		Quantity.	Per cent of production.
	<i>Short tons.</i>	<i>Short tons.</i>	<i>Per cent.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Per cent.</i>
1901-2.	355,611	354,323	99.6	.....	91,909	.....
1902-3.	437,991	431,346	98.5	.....	113,072	.....
1903-4.	367,475	386,773	105.3	.....	129,616	.....
1904-5.	426,248	406,732	95.4	.....	135,660	.....
1905-6.	429,213	402,500	93.8	.....	205,272	.....
1906-7.	440,017	417,038	94.8	.....	204,875	.....
1907-8.	521,123	543,656	104.3	230,094	234,603	102.0
1908-9.	535,156	526,984	98.5	277,093	244,226	88.1
1909-10.	517,090	526,469	101.8	346,786	284,520	82.0
1910-11.	566,821	536,771	94.7	349,840	322,917	92.3
1911-12.	595,038	598,268	100.5	371,076	367,145	98.9
1912-13.	546,524	537,574	98.4	.....	382,710	.....
Average:						
1901-2 to 1905-6.	403,308	396,335	98.3	.....	135,106	.....
1906-7 to 1910-11.	516,041	510,184	98.9	2 300,953	2 271,566	2 90.2

¹ Production in Hawaii 1911-12 and 1912-13 as given by Bureau of Statistics, United States Department of Agriculture; other years by Hawaiian Sugar Planters' Association. Production in Porto Rico as given by the treasury department of Porto Rico. Shipments from Hawaii and Porto Rico to the United States, as given by the Bureau of Foreign and Domestic Commerce, Department of Commerce,

² Average 1907-8 to 1910-11, inclusive.

TABLE 24.—*Sugar made and cane used for sugar in Hawaii, 1910-11 and 1912-13, by islands.*

[From reports of Bureau of Statistics, United States Department of Agriculture. Data for 1911-12 refer to the year ending Sept. 30, 1912; for 1910-11 the data refer to the entire campaign, which for some factories extended later than Sept. 30, 1911. Sugar made during the year ending Sept. 30, 1911, according to the Hawaiian Sugar Planters' Association, was 566,821 short tons.]

Island.	Sugar made (chiefly raw).						Cane used for sugar. ¹		
	Quantity.			Average per short ton of cane. ¹					
	1910-11	1911-12	1912-13	1910-11	1911-12	1912-13	1910-11	1911-12	1912-13
	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
Hawaii.....	198,830	209,914	197,212	228	233	232	1,744,000	1,799,000	1,702,515
Kauai.....	100,667	96,845	100,340	219	240	239	919,000	807,000	840,708
Maui.....	139,894	148,740	124,820	247	277	269	1,133,000	1,074,000	928,590
Oahu.....	135,087	139,539	124,152	260	255	248	1,039,000	1,094,000	1,003,129
Territory of Hawaii.....	574,478	595,038	546,524	238	249	244	4,835,000	4,774,000	4,474,942

¹ Computed from incomplete returns.

TABLE 25.—*Production of sorghum sirup in the United States, 1889, 1899, and 1909, by principal States.*

[Census.]

State.	1889	1899	1909
	<i>Gallons.</i>	<i>Gallons.</i>	<i>Gallons.</i>
Kentucky.....	2,094,962	1,277,206	2,733,683
Tennessee.....	2,542,533	2,047,655	2,076,339
Missouri.....	2,721,240	1,990,987	1,788,391
Arkansas.....	1,868,952	1,223,691	1,140,532
North Carolina.....	1,268,946	1,419,570	1,099,346
Illinois.....	1,110,183	625,939	977,238
Indiana.....	751,808	579,061	965,086
Alabama.....	1,242,689	1,168,868	809,361
Georgia.....	1,342,803	767,024	740,450
Mississippi.....	972,216	1,162,269	622,356
West Virginia.....	512,747	450,777	604,201
Oklahoma.....	31,299	81,891	514,807
Texas.....	1,749,910	877,232	448,185
Virginia.....	540,328	555,321	441,189
Ohio.....	547,630	341,523	354,131
South Carolina.....	559,216	478,190	262,452
Kansas.....	1,484,937	735,787	260,680
Iowa.....	1,386,605	521,212	250,205
Minnesota.....	340,792	157,605	145,934
Wisconsin.....	219,070	160,414	139,667
Louisiana.....	107,763	48,727	47,029
Florida.....	10,461	.....	22,177
Utah.....	24,293	28,017	21,847
Michigan.....	45,524	24,059	21,350
Nebraska.....	634,146	92,413	14,644
All other States.....	118,166	157,345	31,102
United States.....	24,235,219	16,972,783	16,532,382

TABLE 26.—*Sorghum cane area and production in the United States, 1909, by principal States.*

[Census.]

State.	Area.	Production.	Average yield per acre.
	<i>Acres.</i>	<i>Short tons.</i>	<i>Short tons.</i>
Kentucky.....	62,327	226,303	3.6
Tennessee.....	52,907	205,901	3.9
Missouri.....	45,088	201,206	4.5
Texas.....	55,027	101,691	1.8
Arkansas.....	33,071	93,123	2.8
Illinois.....	15,039	90,287	6.0
North Carolina.....	21,227	86,462	4.1
Indiana.....	12,253	79,672	6.5
Alabama.....	17,819	72,388	4.1
Oklahoma.....	25,546	64,599	2.5
Georgia.....	15,612	64,336	4.1
Kansas.....	15,406	60,821	3.9
Mississippi.....	17,851	55,359	3.1
West Virginia.....	8,607	48,094	5.6
Virginia.....	8,288	41,449	5.0
Iowa.....	6,225	28,957	4.7
Ohio.....	4,709	28,644	6.1
South Carolina.....	8,445	27,612	3.3
Wisconsin.....	2,281	13,735	6.0
Minnesota.....	1,709	13,253	7.8
Nebraska.....	4,034	10,477	2.6
Colorado.....	3,169	7,161	2.3
Louisiana.....	1,690	6,073	3.6
California.....	647	3,021	4.7
New Mexico.....	2,371	2,819	1.2
Michigan.....	416	2,765	6.6
Florida.....	379	2,173	5.7
Utah.....	340	1,654	4.9
Arizona.....	586	1,451	2.5
All other States.....	1,020	5,776	5.7
United States.....	444,089	1,647,262	3.7

TABLE 27.—*Maple sugar and sirup production in the United States, 1889, 1899, and 1909, by principal States.*

[Census.]

State.	Maple sugar.			Maple sirup.		
	1889	1899	1909	1889	1899	1909
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>	<i>Gallons.</i>	<i>Gallons.</i>
Vermont.....	14,123,921	4,779,870	7,726,817	213,252	160,918	409,953
New York.....	10,485,623	3,623,540	3,160,300	457,658	413,159	993,242
Pennsylvania.....	1,651,163	1,429,540	1,188,049	154,650	160,297	391,242
New Hampshire.....	2,124,515	441,870	558,811	81,997	41,588	111,500
Maryland.....	156,284	264,160	351,908	1,021	5,825	12,172
Michigan.....	1,641,402	302,715	293,301	197,775	82,997	269,093
Ohio.....	1,575,562	613,990	257,592	727,142	923,519	1,323,431
Massachusetts.....	558,674	192,990	156,952	33,632	27,174	53,091
West Virginia.....	177,724	141,550	140,060	19,032	14,874	31,176
Virginia.....	26,991	19,310	44,976	3,468	1,677	6,046
Indiana.....	67,329	51,900	33,419	180,702	179,576	273,728
Wisconsin.....	128,410	4,180	27,199	48,006	6,625	124,117
All other States.....	235,329	63,155	120,822	135,041	38,382	107,627
United States.....	32,952,927	11,928,770	14,060,206	2,258,376	2,056,611	4,106,418

TABLE 28.—*Production of sugar in countries named, 1901-2 to 1911-12.*

[Substantially the sugar production of the world. Data for 1901-2 to 1905-6 from Willett & Gray, except for a few minor countries; subsequent to 1905-6, from official sources except where otherwise stated. Some figures in this table refer to raw and some to refined sugar, according to the kind stated in the original returns. Some items, especially unofficial data, are subject to revision in case more accurate figures become available.]

Country.	Average per year.		1907-8	1908-9	1909-10	1910-11	1911-12
	1901-2 to 1905-6	1906-7 to 1910-11					
CANE SUGAR.	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
British India ¹	2,171,847	2,345,280	2,292,528	2,097,648	2,382,352	2,483,936	2,677,248
Cuba.....	1,171,810	1,615,152	1,085,616	1,704,416	2,035,600	1,635,200	2,089,920
Java.....	1,006,968	1,325,184	1,333,920	1,368,640	1,368,640	1,377,600	1,582,560
Hawaii.....	403,308	516,041	521,123	535,156	517,090	566,821	595,038
Porto Rico.....	147,392	282,128	230,095	277,093	346,786	349,840	371,076
United States (contiguous).....	² 362,535	² 354,031	² 394,240	² 414,400	² 334,315	² 355,040	360,874
Brazil ²	269,604	275,520	217,280	273,280	278,880	315,840	258,720
Formosa.....	51,923	146,227	72,240	134,848	226,800	³ 226,800	³ 226,800
Philippine Islands ⁴	113,128	145,824	167,216	123,872	140,784	164,640	204,960
Argentina.....	150,820	147,638	124,992	178,192	140,336	163,744	198,464
Queensland.....	135,968	192,931	207,312	168,448	148,736	236,096	194,096
Mauritius ²	190,228	232,579	180,880	215,936	277,760	245,616	186,928
Peru ²	155,426	168,000	148,960	165,760	165,760	181,440	⁵ 181,440
Mexico.....	120,491	153,306	135,856	157,808	163,072	178,080	170,912
British Guiana.....	130,321	⁴ 119,549	⁴ 129,024	⁴ 121,520	⁴ 113,120	⁴ 121,296	⁴ 111,328
Santo Domingo.....	⁶ 54,676	⁴ 82,813	⁴ 69,664	⁴ 77,840	⁴ 102,368	⁴ 101,472	⁴ 107,968
Natal.....	30,831	65,386	35,840	86,800	⁷ 86,800	90,384	101,260
Fiji.....	45,584	70,336	76,496	74,032	77,168	77,056	81,312
Japan.....	(⁸)	61,578	55,104	59,472	64,848	72,464	⁸ 72,464
Egypt.....	82,992	48,384	29,120	40,320	62,720	⁸ 62,720	⁸ 62,720
Trinidad and Tobago.....	50,818	59,920	56,672	54,768	59,360	58,240	52,640
Guadeloupe ⁴	41,913	40,992	39,760	27,776	47,264	47,264	⁸ 47,264
Reunion ⁴	40,732	46,390	52,080	43,456	36,960	48,160	44,800
Martinique ⁴	35,869	42,045	39,648	41,888	44,016	44,016	⁸ 44,016
Jamaica.....	16,272	29,434	31,920	26,880	21,056	31,696	31,808
Portuguese East Africa.....	5,075	11,604	3,360	14,560	19,040	16,800	30,240
Barbados.....	52,425	42,381	42,560	40,768	20,496	45,248	29,904
Spain.....	26,503	19,354	17,696	15,456	23,856	22,400	23,520
Dutch Guiana.....	14,514	13,126	13,104	13,216	12,096	13,328	⁸ 13,328
New South Wales.....	22,854	22,714	32,704	17,136	16,464	21,056	19,040
Antigua.....	12,062	13,933	16,576	14,896	10,304	15,792	13,104
St. Christopher-Nevis.....	15,808	15,187	16,688	13,104	13,776	14,560	⁸ 14,560
Perak.....	18,644	13,350	13,664	12,768	⁹ 13,440	⁹ 13,440	⁸ 13,440
Danish West Indies.....	14,112	11,760	14,112	4,928	13,328	12,992	⁸ 12,992
Guatemala ²	8,529	7,840	7,840	7,840	7,840	7,840	7,840
Salvador ²	6,458	6,720	5,600	6,720	6,720	7,840	7,840
St. Lucia.....	5,155	5,869	5,600	6,160	5,600	5,936	5,040
Costa Rica ²	2,902	2,912	2,240	3,360	3,360	3,360	3,360
Nicaragua.....	4,899	7,392	5,600	11,200	⁷ 11,200	3,360	⁸ 3,360
British Honduras.....	671	650	672	672	448	784	784
St. Vincent.....	701	291	224	224	336	336	336
Dominica.....	246	112	112	112	112	112	112
Montserrat.....	744	358	448	112	112	224	112
Venezuela.....	3,360	(⁹)	(⁹)	(⁹)	(⁹)	(⁹)	(⁹)
Total cane sugar.....	7,197,118	8,762,221	7,926,386	8,653,481	9,421,119	9,440,869	10,255,628

¹ The figures represent the production of about 97 per cent of the area under sugar cane and 90 per cent of the area under all sugar crops.

² Unofficial.

³ Data for 1909-10.

⁴ Exports.

⁵ No data.

⁶ Including Haiti.

⁷ Data for 1908-9.

⁸ Year preceding.

⁹ Average for 1907-8 and 1908-9.

TABLE 28.—*Production of sugar in countries named, 1901-2 to 1911-12—Continued.*

Country.	Average per year.		1907-8	1908-9	1909-10	1910-11	1911-12
	1901-2 to 1905-6	1906-7 to 1910-11					
BEET SUGAR.							
	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
Russia.....	1,209,074	1,454,522	1,380,736	1,242,192	1,122,688	1,208,624	1,025,856
Germany.....	2,207,130	2,444,288	2,357,488	2,291,968	2,245,824	2,854,768	1,650,992
Austria-Hungary.....	1,306,525	1,520,019	1,556,016	1,525,800	1,373,008	1,675,520	1,259,888
United States (contiguous).....	235,517	477,104	463,680	425,600	501,682	510,720	599,500
France.....	986,155	748,563	713,440	785,568	796,880	705,600	501,760
Netherlands.....	170,392	198,464	174,720	217,280	199,360	219,520	302,400
Belgium.....	278,682	278,454	250,208	272,944	263,872	299,040	258,720
Italy.....	104,248	152,544	150,080	182,560	122,080	190,400	184,800
Sweden.....	112,537	156,845	123,200	150,080	140,000	191,744	135,520
Spain.....	80,417	97,440	104,160	119,840	95,200	78,400	95,200
Denmark.....	55,458	76,832	58,016	73,136	69,216	110,768	58,128
Roumania.....	210,718	429,344	425,760	428,000	430,240	530,240	530,240
Canada: Ontario.....	9,055	10,461	10,528	10,528	10,528	10,304	11,088
Servia.....	970	8,176	8,176	8,176	8,176	8,176	8,176
Bulgaria ¹	(7)	6,720	8,960	7,840	6,720	6,720	6,720
Switzerland.....	2,531	3,942	4,144	4,480	4,032	4,032	4,032
Greece.....	(7)	986	448	1,120	1,120	1,120	1,120
Total beet sugar.....	6,969,409	7,664,704	7,389,760	7,350,112	6,990,626	9,005,696	7,134,140
Total beet and cane sugar.....	14,166,527	16,426,925	15,316,146	16,003,593	16,411,745	18,446,565	17,389,768

¹ Sugar made from "beets entering factories."⁵ Data for 1909-10.² Central Union for Beet Sugar Industry.⁶ Average production as unofficially estimated.³ Census for 1909.⁷ No data.⁴ Unofficial.⁸ Data for 1908-9.TABLE 29.—*Percentage of the "world" sugar crop produced in each principal country, 1901-2 to 1911-12.¹*

Country.	Average per year.		1907-8	1908-9	1909-10	1910-11	1911-12
	1901-2 to 1905-6	1906-7 to 1910-11					
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
British India.....	15.3	14.3	15.0	13.1	14.5	13.5	15.4
United States and insular possessions.....	8.9	10.8	11.6	11.1	11.2	10.6	12.3
Cuba.....	8.3	9.8	7.1	10.7	12.4	8.9	12.0
Russia.....	8.5	8.9	9.0	7.8	6.8	11.4	11.6
Germany.....	15.6	14.9	15.4	14.3	13.7	15.5	9.5
Java.....	7.1	8.1	8.7	8.6	8.3	7.5	9.1
Austria-Hungary.....	9.2	9.3	10.2	9.6	8.4	9.1	7.2
France.....	7.0	4.6	4.7	4.9	4.9	3.8	2.9
Netherlands.....	1.2	1.2	1.1	1.4	1.2	1.2	1.7
Brazil.....	1.9	1.7	1.4	1.7	1.7	1.7	1.5
Belgium.....	2.0	1.7	1.6	1.8	1.6	1.6	1.5
Formosa.....	.4	.9	.5	.8	1.4	1.2	1.3
Argentina.....	1.1	.9	.8	1.1	.9	.9	1.1
Australian Commonwealth: Queensland.....	1.0	1.2	1.4	1.1	.9	1.3	1.1
Mauritius.....	1.3	1.4	1.2	1.3	1.7	1.3	1.1
Italy.....	.7	.9	1.0	1.1	.7	1.0	1.1
Peru.....	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Mexico.....	.9	.9	.9	1.0	1.0	1.0	1.0
Sweden.....	.8	1.0	.8	.9	.9	1.0	.8
Spain.....	.8	.7	.8	.8	.7	.5	.7
British Guiana.....	.9	.7	.8	.8	.7	.7	.6
Santo Domingo.....	.4	.5	.5	.5	.6	.6	.6
Other countries.....	5.6	4.6	4.5	4.6	4.8	4.7	4.9
Total.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0

¹ See notes to Table 28.

TABLE 30.—Percentage of cane and beet sugar in the total "world" production, 1901-2 to 1911-12.¹

Year.	Cane sugar.		Beet sugar.		Total.
	Quantity.	Per cent of total.	Quantity.	Per cent of total.	
Average:	<i>Short tons.</i>	<i>Per cent.</i>	<i>Short tons.</i>	<i>Per cent.</i>	<i>Short tons.</i>
1901-2 to 1905-6.....	7,197,118	50.8	6,969,409	49.2	14,166,527
1906-7 to 1910-11.....	8,762,221	53.3	7,664,704	46.7	16,426,925
1907-8.....	7,926,386	51.8	7,389,760	48.2	15,316,146
1908-9.....	8,653,481	54.1	7,350,112	45.9	16,003,593
1909-10.....	9,421,119	57.4	6,990,626	42.6	16,411,745
1910-11.....	9,440,869	51.2	9,005,696	48.8	18,446,565
1911-12.....	10,255,628	59.0	7,134,140	41.0	17,389,768

¹ See notes to Table 28.

TABLE 31.—International trade in sugar, calendar years 1901-1911.

EXPORTS.

Country from which exported.	Average per year.		1907	1908	1909	1910	1911
	1901-1905	1906-1910					
	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
Cuba.....	1,009,172	1,461,755	1,455,219	995,509	1,603,323	1,932,871	¹ 1,932,871
Dutch East Indies.....	1,004,045	1,306,083	1,316,112	1,411,847	1,386,964	1,316,899	² 1,476,151
Germany ³	1,037,362	995,500	1,007,630	921,056	941,299	771,601	945,023
Austria-Hungary.....	700,005	826,347	809,430	884,505	878,531	743,306	667,479
France.....	402,946	284,870	365,630	270,410	267,879	211,536	² 146,823
Mauritius.....	185,037	214,749	215,672	217,208	197,700	237,814	261,408
Russia.....	173,156	204,936	198,458	329,131	225,953	164,116	500,064
Belgium.....	177,803	171,896	189,782	146,573	159,660	132,632	180,080
Netherlands.....	156,236	165,717	149,984	169,898	168,048	160,631	216,179
Philippine Islands.....	96,251	143,940	141,003	159,541	142,558	133,898	230,039
Peru.....	137,828	136,783	121,931	137,668	138,175	135,424	¹ 135,424
British Guiana ⁴	128,808	121,047	112,825	129,039	121,557	113,068	111,292
Santo Domingo.....	66,724	73,149	54,105	69,703	77,822	102,413	² 96,749
Fiji Islands.....	50,338	65,824	74,589	74,087	68,127	69,172	81,574
Brazil.....	86,293	56,590	14,173	34,808	75,489	² 64,841	² 39,912
Trinidad and Tobago ⁴	48,545	49,835	51,823	44,372	50,770	51,797	42,489
Reunion.....	37,129	44,774	51,257	52,066	43,408	36,927	¹ 36,927
Martinique.....	32,596	42,554	40,703	39,605	41,864	44,043	¹ 44,043
Guadeloupe.....	39,935	41,074	42,946	39,744	27,791	47,253	¹ 47,253
Barbados.....	53,710	38,131	38,054	36,119	17,937	40,218	30,785
United Kingdom.....	39,618	37,772	37,710	29,636	36,131	35,128	32,005
British India.....	27,143	22,784	23,292	23,178	18,453	25,693	22,092
China.....	35,861	12,824	7,447	16,100	11,293	17,726	16,793
Egypt.....	41,220	5,329	4,603	4,319	4,943	7,533	11,908
Argentina.....	31,296	63	71	20	44	61	75
Other countries.....	140,894	285,104	257,753	233,730	288,966	354,843	² 248,102
Total.....	5,939,951	6,809,428	6,782,202	6,469,872	6,994,685	6,951,444	7,553,540

¹ Year preceding.² Not including free ports prior to Mar. 1, 1906.² Preliminary.⁴ Year beginning Apr. 1.

TABLE 31.—*International trade in sugar, calendar years 1901-1911—Continued.*

IMPORTS.

Country into which imported.	Average per year.		1907	1908	1909	1910	1911
	1901-1905	1906-1910					
	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>	<i>Short tons.</i>
United States.....	1,874,989	1,947,656	1,936,111	1,859,350	1,908,448	2,097,538	2,067,103
United Kingdom.....	1,691,729	1,770,275	1,767,861	1,747,596	1,831,663	1,793,944	1,859,430
British India.....	325,098	608,257	536,989	592,545	627,030	673,367	635,570
China.....	248,125	349,618	381,592	277,484	365,211	287,422	287,717
Canada.....	188,845	240,303	222,501	219,655	261,279	267,246	299,883
Japan.....	236,839	195,347	219,759	221,569	149,434	133,563	87,636
Turkey.....	139,707	¹ 151,309	¹ 151,309	¹ 151,309	¹ 151,309	¹ 151,309	¹ 151,309
France.....	108,998	126,616	119,083	127,132	119,279	156,308	² 189,661
Switzerland.....	89,915	101,897	102,775	100,710	100,504	111,671	115,431
Persia ³	85,316	99,070	95,712	93,651	100,623	⁴ 100,623	⁴ 100,623
Netherlands.....	103,055	75,740	98,270	70,579	78,018	70,836	102,183
Chili.....	49,993	66,257	62,558	53,404	76,881	79,182	95,485
Singapore.....	52,345	56,706	51,276	45,632	62,670	56,718	⁵ 56,718
New Zealand.....	43,373	50,828	37,794	51,332	58,221	57,766	61,979
Norway.....	40,234	45,500	43,546	43,537	49,339	50,898	53,114
Finland.....	34,541	45,484	43,842	45,084	48,788	48,043	49,091
Australia.....	77,548	45,145	6,946	21,959	111,662	38,089	37,269
British South Africa.....	(⁶)	43,848	53,233	45,743	33,661	30,174	37,353
Egypt.....	18,885	42,802	27,436	58,703	54,202	35,509	50,448
Portugal.....	33,816	36,813	36,483	36,660	38,594	36,283	36,283
Argentina.....	268	36,094	47,975	45,827	21,842	62,692	57,298
Denmark.....	34,514	31,562	26,541	41,326	42,162	25,152	12,739
Uruguay ⁷	20,803	26,606	23,416	28,543	⁸ 28,543	⁸ 28,543	⁸ 28,543
Italy.....	15,676	13,550	26,166	5,398	13,057	7,215	10,418
Other countries.....	240,023	278,322	265,982	297,741	305,369	303,355	² 315,611
Total.....	5,754,635	6,485,605	6,385,156	6,282,469	6,637,789	6,703,446	6,798,895

¹ Data for year beginning Mar. 14, 1905.² Preliminary.³ Year beginning Mar. 21.⁴ Data for 1909.⁵ Year preceding.⁶ South African Customs Union formed in 1905. Returns for separate colonies included in "Other countries" for years prior to 1906.⁷ Year beginning July 1.⁸ Data for 1908.

NOTE.—This table covers substantially the trade of the world. It should not be expected that the world export and import totals for any year will agree. Among sources of disagreement are these: (1) Different periods of time covered in the "year" of the various countries; (2) imports received in year subsequent to year of export; (3) want of uniformity in classification of goods among countries; (4) different practices and varying degrees of failure in recording countries of origin and ultimate destination; (5) different practices of recording reexported goods; (6) opposite methods of treating free ports; (7) clerical errors, which, it may be assumed, are not infrequent; (8) losses at sea.

The exports given are domestic exports, and the imports given are imports for consumption as far as it is feasible and consistent so to express the facts. While there are some inevitable omissions, on the other hand there are some duplications because of reshipments that do not appear as such in official reports. For the United Kingdom, import figures refer to imports for consumption when available; otherwise total imports less exports of "foreign and colonial merchandise."

The following kinds and grades have been included under the head of sugar: Brown, white, candied, caramel, *chancaca* (Peru), crystal cube, maple, muscovado, panela. The following have been excluded: "Candy" (meaning confectionery), confectionery, glucose, grape sugar, jagery, molasses, and sirup.

Some figures in this table refer to raw and some to refined sugar, according to the kind reported in the original returns. In the statistics of the foreign trade of the United States, the Philippine Islands are treated as a foreign country; all other noncontiguous possessions, as part of the United States.

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No. 67



Contribution from the Forest Service, Henry S. Graves, Forester.
March 17, 1914.

(PROFESSIONAL PAPER.)

TESTS OF ROCKY MOUNTAIN WOODS FOR TELEPHONE POLES.

By NORMAN DE W. BETTS and A. L. HEIM,
Engineers in Forest Products.

POLE SUPPLY IN THE ROCKY MOUNTAIN REGION.

The rapid extension of telephone and power lines in the West makes the question of pole supply one of increasing importance. Tests described in this bulletin show that both green and fire-killed lodgepole pine and fire-killed Engelmann spruce will, under certain conditions, make suitable pole timbers. Western red cedar has long been the standard pole timber in the Western States. It has held its place mainly on account of its durability in contact with the soil, though its light weight has also been a very desirable feature. The tree (*Thuja plicata*) grows principally in Washington, Oregon, and northern Idaho. In addition to its wide use for poles, it is extensively cut for lumber, and especially for shingles. In the States south of its region of growth the cost of cedar is high, owing to the great distances over which it must be transported. Moreover, the heavy drain on the available supply must soon result in higher stumpage prices. There are at present in both the Rocky Mountain and Coast Ranges abundant stands of lodgepole pine (*Pinus contorta*), often called by local lumbermen "white pine," of little value for lumber, but well adapted for poles. Lodgepole pine is not naturally durable in contact with the ground, and for that reason has not been able to enter the field as a competitor of western red cedar. The general adoption of preservative treatment¹ by railroad and telephone companies, however, has changed the situation. At an additional cost for treatment that still leaves the pine pole the cheaper of the two in most of the markets outside the region where cedar grows, the pine may be made to last longer than untreated cedar. Lodgepole

¹ The preservative treatment of poles is discussed in Forest Service Bulletin 84.

NOTE.—This bulletin gives the results of tests on western red cedar, lodgepole pine, and Engelmann spruce poles to determine their suitability for telephone lines. Values are presented for fiber stress at elastic limit, modulus of rupture, stiffness, and modulus of elastic resilience. Of value to lumbermen in the Rocky Mountain and Pacific Coast States and to users of telephone poles.

**ENGELMANN SPRUCE****LODGEPOLE PINE****WESTERN RED CEDAR**

FIG. 1.—Botanical range of western red cedar, lodgepole pine, and Engelmann spruce.

pine takes treatment readily. Cedar, on the other hand, allows but a very shallow penetration.

Another tree, Engelmann spruce (*Picea engelmanni*) also has a wide distribution throughout the Rocky Mountains, although it grows commercially only at the higher altitudes. It is thus not as available as the lodgepole pine, nor in shape or in its ability to take preservative treatment is it so well adapted for poles. It grows farther south, however, and in many districts is the only native timber available for pole use. Figure 1¹ shows the botanical range of growth of the three species. The relatively restricted range of western red cedar indicates the importance to the more southern mountain States of determining the value of local timbers for telephone and power line poles.

Forest fires in the Rocky Mountains have killed many stands of spruce and pine, and the disposal of this material, which, through checking, is rendered practically useless for saw timber, has always been a troublesome problem. On many areas such material remains entirely sound for a number of years after the fire, and, besides, is thoroughly seasoned and thus ready for treatment as soon as cut. In some regions the mines use all the available dead timber, though elsewhere there is a great deal of prejudice against the use of "fire-killed" material, under the mistaken assumption that there is some inherent difference in wood that has been seasoned on the stump and wood that has been cut when green.

The purpose of the tests described in this bulletin was: (1) To compare the strength of poles of western red cedar, the present standard, and of lodgepole pine and Engelmann spruce, and (2) to determine the value for pole timber of fire-killed pine and spruce in the central Rocky Mountain region.

The fire-killed material was donated by the Colorado Telephone Co. and the Central Colorado Power Co. The remainder of the material tested was secured by the Forest Service, either by purchase or from the National Forests. The tests were made at the Forest Service timber-testing laboratory conducted in cooperation with the University of Colorado, Boulder, Colo.

MATERIAL TESTED.

The material for the tests consisted of poles nominally 25 feet long and of 7 inches top diameter. Average material was specified in each case.

WESTERN RED CEDAR.

Twenty cedar poles were purchased on the Denver market at a cost of \$4 per pole. Information furnished by the seller showed the poles to have been cut during the winter of 1908-9, near Edgemere, Idaho. When received at the laboratory they appeared to be

¹ Distribution maps prepared by Office of Dendrology.

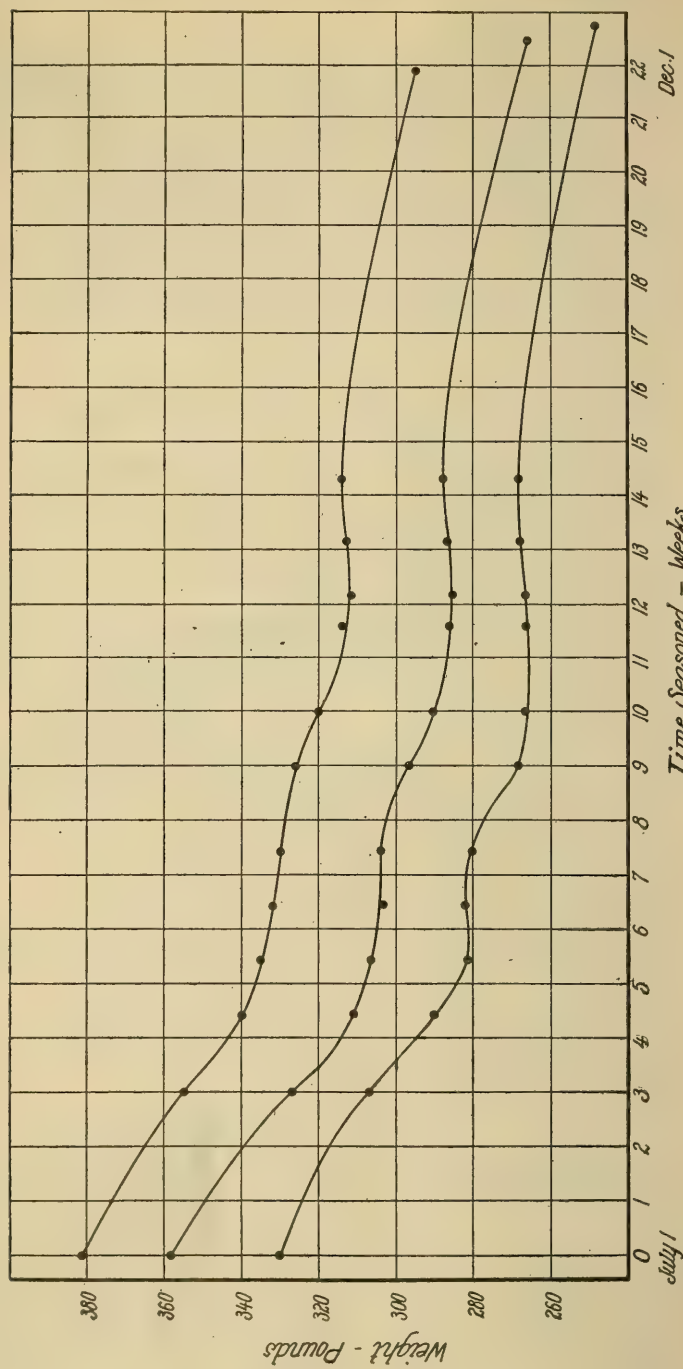


FIG. 2.—Rate of seasoning for three lodgepole pine poles.

thoroughly seasoned, the bark probably having been removed at the time of cutting. All were nearly straight, and checked to the extent usual for seasoned material. A majority had straight grain.

GREEN LODGEPOLE PINE.

Twenty-two lodgepole pine poles were cut near Anaconda, Mont., in July, 1911, on the Deerlodge National Forest, in a dense stand

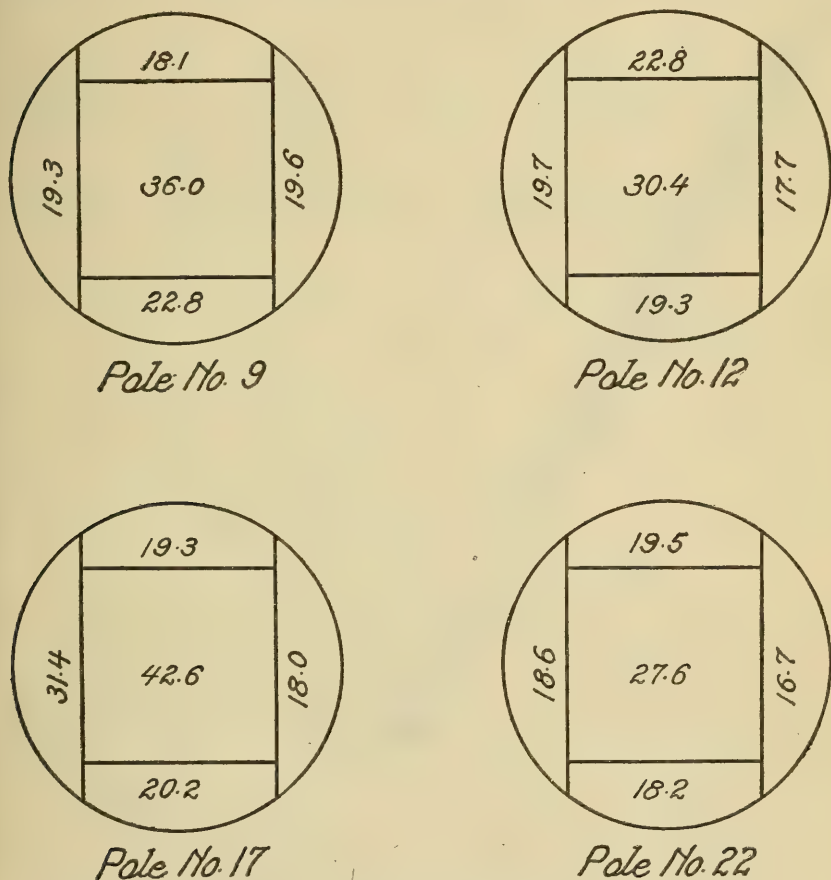


FIG. 3.—Moisture distribution in four air-seasoned lodgepole pine poles. Figures indicate per cent moisture within areas.

on a gentle west slope at an elevation of about 6,500 feet. Upon arrival at the testing laboratory the poles were open-piled in two layers for seasoning. Three poles were weighed at approximately weekly intervals to determine the rate of drying. Figure 2 shows graphically the rate based on these weights. Based on their shipping weight the poles had an average moisture content of 60 per cent when shipped. Assuming that the three poles represent the average of the shipment, the poles had dropped to 48 per cent moisture by

FIRE-KILLED LODGEPOLE PINE AND ENGELMANN SPRUCE.

Twenty poles each of fire-killed lodgepole pine and Engelmann spruce were cut near Norrie, Colo., on a north slope at an elevation of about 10,000 feet. The area had been burned over by a light fire about 10 years¹ previously. The poles were largely free of bark, though a majority had patches here and there, showing that no serious weathering of the surface had taken place.

METHODS OF TEST.

Figure 4 shows the method employed in testing. The poles were supported about 1 foot from each end in bearing blocks (*e, e*) resting on rocker supports (*f, d*) 23 feet apart. The load was applied by a universal testing machine through a bearing block (*t*) 5 feet from the butt end of the pole, or 4 feet from the center line of the butt support. The rocker support (*d*) rested on a pier (*c*) built on the floor. The rocker support (*f*) rested at the center of the auxiliary beam (*g*), one end of which was supported by a rail (*b*) and two piers (*a, a*). The other end of the auxiliary beam (*g*) rested on a roller (*k*) in the center of the weighing platform (*h*) of the machine. As the load was gradually applied at *t* the pole deflected, and the scale at *n*, at the center of the span, moved down with respect to a taut spring (*p*) stretched between pins driven into the pole on the neutral axis directly over the supports. The deflection of the pole at the load point was read on a scale (*m*), which gave the movement of the machine head (*t*) with reference to the platform (*h*).

Corresponding readings of the applied load, the deflection at the load point, and the deflection at the middle of the span were taken at convenient intervals, and plotted as shown in figure 5, until the pole was broken. The settling of the pole in the bearing blocks and deflection of the auxiliary beam (*g*) introduced slight errors in the determination of the deflection. The total error was estimated as less than 3 per cent within the elastic limit, and the only calculated results affected by this (which was practically constant for all the poles) are the stiffness factor and elastic resilience, both of which are comparable only with results from tests of the same nature.

From each pole after test a 30-inch section of clear wood was taken and cut into 2 by 2 inch sticks. These were tested in bending, in compression parallel to the grain, compression perpendicular to the grain, and shearing. The method employed in making these minor tests is discussed fully in Forest Service Circular 38 (revised). The purpose of these tests was to determine the influence of defects on the strength of the poles.

The poles in each of the four lots were given consecutive numbers starting with 1, in order to distinguish between the individual poles of each lot.

¹ The date of the fire was obtained from local residents.

To determine the moisture content, a 1-inch section was cut from each pole as near as possible to the point of failure, immediately weighed, and later dried to constant weight at the temperature of

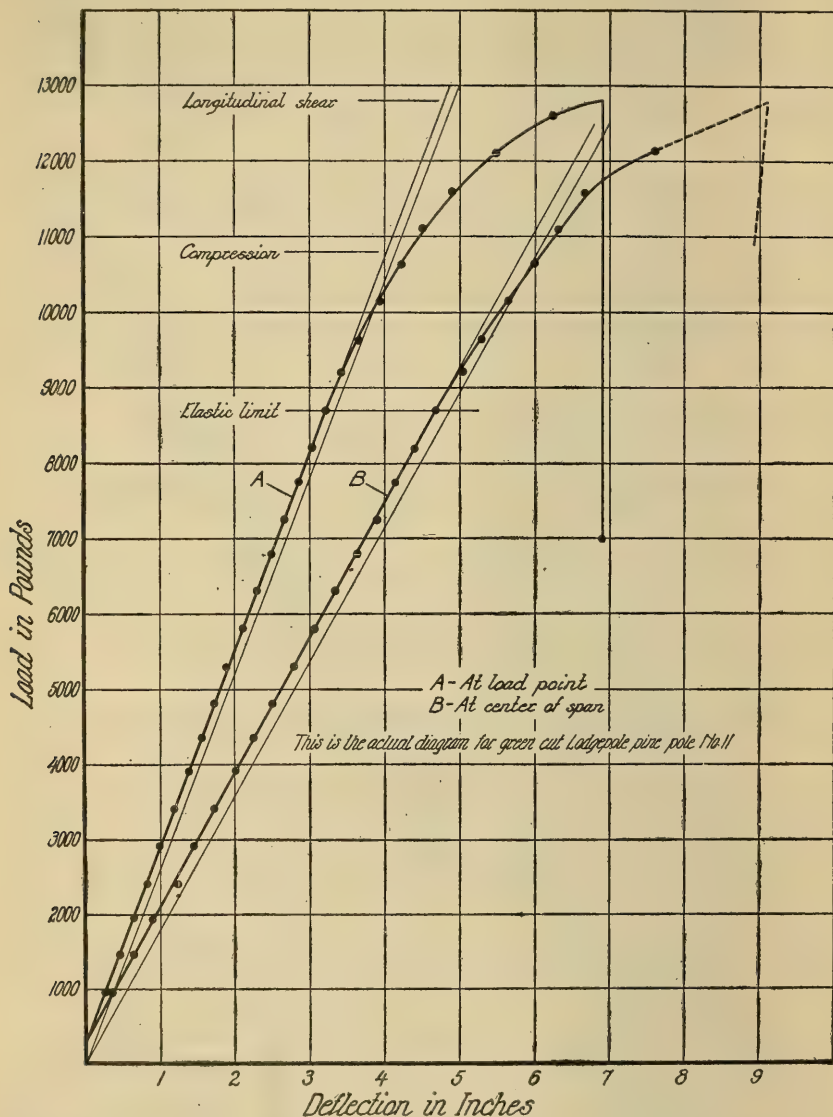


FIG. 5.—Typical load-deflection diagram for poles. (This is actual curve for green cut lodgepole pine pole No. 11.)

boiling water. The loss in weight divided by the dry weight is expressed in per cent of moisture.

The length, weight, and diameters of the poles were obtained just before testing. The age, rings per inch, per cent sap, and per cent summerwood were obtained after test from a section cut near the

point of failure. The values for the amount of summerwood were obtained on a 2-inch length taken from an average portion of the section. Sketches were made of the manner of failure, principal defects, and any characteristics peculiar to the poles tested.

METHOD OF COMPUTING RESULTS.

The deflections and loads at elastic limit were taken from the load-deformation curves, a sample of which is shown in figure 5. To reduce the load recorded on the scale beam to the true load on the pole, all recorded values were multiplied by $\frac{23}{19} \times 2$, and appear in the tables in the corrected form. Stresses at elastic limit and maximum load were calculated for the outer fiber under the load point. The moment of three-fourths of the weight of the pole was added to the moment produced by the load. The comparative stiffness is expressed by the relation $\frac{P}{Id}$, when P is the load at elastic limit and I and d , respectively, the moment of inertia and the deflection at elastic limit measured at the load point.

The modulus of elastic resilience was obtained from the formula one-half $Pd \div$ volume. In obtaining the volumes there was found to be considerable difference in the shape of the poles. The spruce and pine were practically of even taper, and the volumes obtained by regarding the whole pole as one frustum of a cone (from top to butt diameter), or as two frustums (from top to center and center to butt), were practically the same. In the cedar, however, it was found necessary, on account of the flared butts, to use a three-frustum method (from top to center, from center to load point, and from load point to butt). There was about 10 per cent difference between results from the one and the three frustum methods with this species. In calculating the dry weight per cubic foot, a total shrinkage of 12 per cent for the fire-killed pine and spruce was assumed, and 10 per cent for the cedar. The air-seasoned pine poles were considered as being one-third below the fiber saturation point (that is, a 4 per cent shrinkage in volume was assumed as having already occurred), and the others were assumed as being half-way between the dry and the fiber-saturated states.

RESULTS OF TESTS.

CHARACTER OF FAILURES.

Figure 6 shows the common types of failures occurring in the poles tested.

The bend of the pole while under load was at a maximum near the center of the span for the first part of the test and about 2 feet nearer the load point at maximum load. This shifting at the point

of greatest deflection was most noticeable in the poles having a tendency toward longitudinal shear. The effect of knots was in evidence only as localizing the compression wrinkles and occasionally

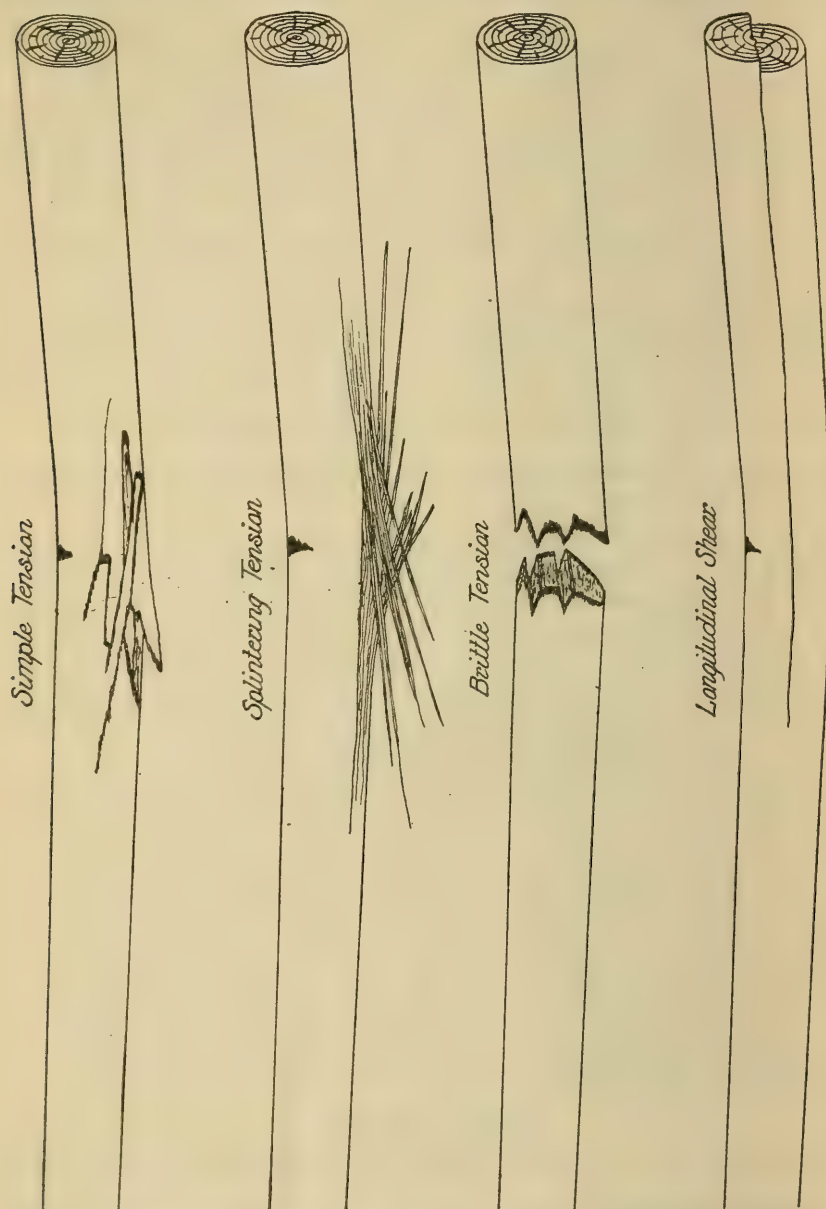


FIG. 6.—Types of failures in poles.

at the starting point of a tension crack. In the cedar poles many shallow ax cuts had been made when the bark was removed, and tension failures always took advantage of these breaks in the fibers.

There seemed to be no consistent difference in the behavior of straight and spiral grain poles.

The typical failure of the western red cedar poles was a splintering tension about 2 feet from the load point. The wood separated easily along the annual rings, and the splinters were long and numerous. Probably due to this quality, as well as to the depth of checks, three poles failed in longitudinal shear, and in two others shear occurred after the maximum load had been passed.

In the air-seasoned lodgepole pine poles there were 18 tension failures and 4 failures from longitudinal shear. Of the 18 tension failures, 9 were of the splintering type characteristic of the cedar poles and 9 were simple tension failures; that is, without the exhibition of brittleness or unusual splintering.

The typical failure in fire-killed lodgepole pine was a simple tension close to the load point. The wood often had a rather brash appearance, and, except for two poles, did not splinter to any extent. One pole was brittle, failing near the center, and one failed by longitudinal shear after the maximum load had been passed.

In general the fire-killed Engelmann spruce poles failed in the same manner as the fire-killed lodgepole pine. Two poles had brittle tension failures, and there were no longitudinal shear failures.

The fact that 9 of the 42 air-seasoned and only 1 of the 40 fire-killed poles failed by longitudinal shear might seem at first to indicate that the checking of the poles cut from green timber is deeper than that occurring in the more slowly drying fire-killed poles. The fact, however, that the average shearing stress of the cedar proved to be about 15 per cent lower than that of the other species, and further that the moduli of rupture in bending of both green-cut shipments were higher than those obtained in both fire-killed shipments, shows that there was a greater chance for shear failures in the air-seasoned material than in the fire-killed, aside from any difference in the manner of checking.

Compression of the upper fibers, as shown by wrinkles on the top of the pole, occurred some time before the maximum load was reached. There was usually a noticeable increase in the bend of the load-deflection curve after compression became visible.

TABLE 1.—*Results of individual tests.*
WESTERN RED CEDAR POLES CUT GREEN AND AIR SEASONED.

Pole and reference No.	Grain.	Per cent moisture.	Weight of pole at feet.	Length.	Diameter at—				Approximate age.	Rings per inch.	Per cent summerwood.	Per cent sap.	Weight per cubic foot (oven dry).	Fiber stress at elastic limit.	Modulus of rupture.	Stiffness factor.	Modulus of elastic resilience.	Manner of failure.
					Top.	Center.	Load point.	Butt.										
1	Straight.....	15.5	222	302	7.06	8.28	8.99	10.03	84	20	.....	24	20.9	2,900	5,560	6.07	1.19	Tension at load; split along shake.
2	do.....	16.4	211	304	6.58	7.58	8.58	10.17	101	22	23	37	22.0	3,945	6,370	6.04	.92	Simple tension 40 inches from load.
3	do.....	16.7	240	305	7.03	9.00	9.87	11.10	104	20	22	33	19.3	3,530	5,400	4.43	.94	Simple tension 78 inches from load, separation on annual rings.
4	do.....	15.8	228	304	7.16	8.22	9.53	10.51	97	19	18	43	20.5	2,900	5,560	4.62	.62	Splintering tension 66 inches from load.
5	do.....	30.8	233	303	6.78	7.75	9.10	10.58	91	18	21	38	20.2	3,990	5,480	4.99	1.09	Splintering tension 36 inches from load.
6	do.....	14.5	224	304	7.20	7.96	8.85	10.19	94	21	25	27	21.8	3,770	6,930	6.58	.68	Splintering tension at load.
7	do.....	17.3	247	304	7.32	8.75	9.91	11.61	68	13	13	29	19.6	3,780	5,090	4.46	1.08	Splintering tension 12 inches from load.
8	Spiral.....	18.5	208	303	6.98	7.90	8.47	10.67	83	19	14	37	20.2	4,130	6,870	7.43	.68	Simple tension at load.
9	Straight.....	13.0	192	303	6.15	7.48	8.00	8.77	55	14	17	38	23.1	5,350	8,120	8.90	1.00	Do.
10	Spiral.....	14.2	251	299	6.84	8.28	9.37	11.50	83	17	22	36	22.9	4,500	6,650	6.30	1.06	Splintering tension at load.
11	Straight.....	13.5	210	304	6.96	7.98	8.57	8.75	83	19	20	26	22.2	4,610	5,550	8.50	.80	Longitudinal shear along checks.
12	do.....	14.1	259	304	7.18	8.38	9.65	11.44	101	20	18	21	22.5	4,230	7,720	6.25	.96	Tension and compression followed by shear.
13	do.....	13.8	245	305	7.19	8.36	9.37	11.40	101	20	21	32	21.8	4,260	6,770	5.64	1.03	Splintering tension 48 inches from load.
14	do.....	12.1	179	304	6.37	7.33	7.97	8.52	81	20	17	27	22.4	4,940	8,220	8.49	.92	Splintering tension 24 inches from load.
15	do.....	12.0	202	304	6.89	7.88	8.76	10.11	69	17	17	32	20.7	3,880	7,600	6.40	.75	Tension and compression followed by shear.
16	do.....	12.6	195	303	6.89	7.79	8.11	8.22	79	20	18	25	22.2	5,980	8,190	9.05	1.21	Longitudinal shear.
17	do.....	14.5	239	297	7.46	8.38	9.11	9.65	79	17	20	38	22.4	5,030	6,830	6.70	1.22	Splintering tension 24 inches from load.
18	Spiral.....	12.2	200	306	6.83	7.84	8.47	10.10	69	16	17	33	21.0	4,450	7,800	7.62	.80	Splintering tension 36 inches from load.
19	do.....	12.1	219	304	7.42	8.06	8.83	11.80	71	15	11	29	20.4	4,500	6,640	7.10	.85	Do.
20	Straight.....	12.0	238	303	7.25	8.22	8.50	10.12	95	21	17	24	22.1	5,700	9,360	9.46	1.01	Longitudinal shear.
	Average.....	15.1	222	302	6.95	8.07	8.90	10.26	84	18	18	32	21.4	4,430	6,885	6.75	.94	
	Maximum.....	30.8	259	304	7.46	9.00	9.91	11.80	104	22	25	43	23.1	5,980	9,360	9.46	1.22	
	Minimum..	12.0	179	303	6.15	7.33	7.97	8.22	55	13	11	21	19.3	2,900	5,090	4.43	.62	

LODGEPOLE PINE POLES CUT GREEN AND AIR SEASONED.

1	Spiral.....	21.9	363	308	8.30	9.38	10.00	11.00	165	30	.....	48	25.5	3,830	5,190	6.35	0.69	Simple tension 12 inches from load.
2	Straight.....	20.9	252	306	6.90	7.75	8.50	9.50	161	34	.....	39	25.5	4,580	6,830	7.30	.88	Splintering tension 18 inches from load.
3	Spiral.....	21.0	257	307	6.70	7.50	8.30	8.70	155	35	.....	53	28.6	5,600	7,700	7.13	1.43	Simple tension 12 inches from load.

LODGEPOLE PINE POLES FIRE KILLED 10 YEARS.

4	Straight.....	21.8	314	305 $\frac{1}{2}$	7.60	8.60	9.20	10.00	165	33	.....	63	26.6	5,650	8,290	8.47	1.16	Splintering tension 12 inches from load.
5	Spral.....	21.4	286	308 $\frac{1}{2}$	7.00	7.68	8.25	8.75	149	34	.....	56	28.4	5,840	8,050	8.81	.81	Simple tension 12 inches from load.
6	do.....	19.7	300	308 $\frac{1}{2}$	7.10	7.65	8.15	8.65	162	38	.....	56	29.6	5,390	9,500	10.60	.....	Splintering tension 18 inches from load.
7	do.....	24.5	318	307 $\frac{1}{2}$	6.75	7.65	8.30	9.00	165	36	.....	42	28.5	5,380	7,000	7.01	1.43	Splintering tension 12 inches from load.
8	do.....	24.0	275	307 $\frac{1}{2}$	8.00	8.90	9.50	10.00	165	33	.....	58	29.0	5,200	7,790	9.07	.93	Longitudinal shear.
9	Spral.....	21.4	317	309	7.70	8.65	9.40	10.25	139	31	.....	35	26.0	5,700	7,790	8.41	1.13	Splintering tension 12 inches from load; brash.
10	do.....	24.5	296	307	7.25	8.00	8.40	8.75	162	37	.....	39	29.1	5,700	7,750	9.62	1.03	Simple tension 8 inches from load.
11	Straight.....	22.8	351	308 $\frac{1}{2}$	7.50	8.25	9.00	9.50	139	33	.....	46	25.5	4,940	7,210	8.00	.96	Longitudinal shear.
12	do.....	23.2	285	318 $\frac{1}{2}$	8.00	9.00	9.25	9.70	170	35	.....	37	27.2	4,830	7,380	8.66	.79	Simple tension at load.
13	do.....	21.8	351	309 $\frac{1}{2}$	7.80	8.80	9.25	9.50	166	33	.....	57	29.6	5,920	7,470	8.90	1.22	Splintering tension 18 inches from load.
14	Straight.....	18.5	305	307 $\frac{1}{2}$	6.90	7.70	8.50	9.25	160	35	.....	56	27.5	5,920	9,230	10.80	.95	Longitudinal shear.
15	Spral.....	19.4	268	307 $\frac{1}{2}$	6.75	7.70	8.15	9.20	166	36	.....	57	28.4	5,310	7,640	9.39	.88	Do.
16	do.....	21.4	334	305 $\frac{1}{2}$	6.80	8.30	9.50	11.00	165	30	.....	38	27.4	5,270	7,950	9.58	.89	Simple tension 24 inches from load.
17	do.....	21.4	272	305 $\frac{1}{2}$	6.85	7.75	8.20	8.50	161	38	.....	49	29.7	5,770	8,530	9.52	1.05	Do.
18	do.....	19.4	313	305 $\frac{1}{2}$	7.50	8.45	9.00	10.00	165	33	.....	59	27.7	5,280	6,410	7.35	.83	Splintering tension 24 inches from load.
19	do.....	34.8	373	309 $\frac{1}{2}$	7.85	9.25	9.60	9.85	144	29	.....	37	26.1	4,330	6,540	7.92	.83	Simple tension at load.
20	Straight.....	20.4	335	307 $\frac{1}{2}$	7.70	8.75	9.60	10.25	167	33	.....	51	27.5	4,530	6,450	7.92	.83	Splintering tension at load.
21	do.....	18.5	270	307	6.75	7.70	8.30	9.30	168	36	.....	75	28.7	5,950	8,860	9.78	1.10	Do.
22	do.....	20.4	248	306 $\frac{1}{2}$	6.75	7.70	8.15	8.75	170	39	.....	43	26.9	6,270	8,670	9.47	1.27	Do.
23	Average.....	21.9	304	.....	7.36	8.28	8.85	9.52	162	34	.....	48	27.6	5,280	7,080	8.62	1.00	Do.
24	Maximum.....	34.8	384	.....	8.30	9.38	10.00	11.00	170	39	.....	75	29.6	6,270	9,500	10.80	1.43	Do.
25	Minimum.....	18.5	248	.....	6.70	7.65	8.15	8.50	144	29	.....	34	25.5	3,830	5,190	6.35	.69	Do.

LOGPOLE PINE POLES FIRE KILLED 10 YEARS.

1	Straight.....	11.2	250	310	7.30	8.60	.....	9.60	140	27	11	21	23.1	2,230	2,230	4.42	0.34	Brittle tension 108 inches from load.
2	do.....	14.6	267	309 $\frac{1}{2}$	7.25	8.50	.....	9.50	142	32	14 $\frac{1}{2}$	32	24.6	3,355	3,495	5.70	.62	Not tested; broken in shipment.
3	do.....	11.9	310	311 $\frac{1}{2}$	7.50	8.50	.....	9.25	184	38	16	20	28.1	6,130	6,540	8.46	1.38	Simple tension 96 inches from load; brash.
4	do.....	22.4	286	309 $\frac{1}{2}$	7.25	8.62	.....	9.00	143	29	17	36	25.0	5,000	7,480	8.72	.84	Do.
5	do.....	12.8	270	309	6.75	8.12	.....	8.75	130	29	13	21	28.4	5,800	7,140	6.68	1.62	Simple tension at load.
6	do.....	12.9	303	311 $\frac{1}{2}$	7.75	8.50	.....	9.50	170	34	18	37	27.4	5,560	7,420	6.63	1.45	Simple tension 84 inches from load.
7	do.....	16.8	273	311 $\frac{1}{2}$	7.50	9.00	.....	9.00	189	39	19	45	23.5	4,940	5,720	7.08	1.03	Do.
8	do.....	20.8	411	312	7.25	10.25	.....	10.75	97	17	14	27	24.7	2,605	3,775	5.18	.38	Simple tension at load; brash.
9	Spral.....	19.7	294	312	7.25	8.88	.....	9.50	148	31	15	60	24.5	3,575	5,610	6.11	.64	Simple tension 12 inches from load.
10	do.....	18.2	305	309 $\frac{1}{2}$	7.50	8.88	.....	9.00	152	31	15	40	26.5	5,030	7,030	7.04	1.07	Simple tension at load; brash.
11	Straight.....	14.8	315	311	7.25	9.00	.....	10.50	170	28	19	30	24.5	4,730	6,710	4.91	1.54	Simple tension 48 inches from load.
12	do.....	13.9	260	310 $\frac{1}{2}$	7.25	8.62	.....	14.75	140	33	9	37	24.3	4,130	5,290	6.02	.99	Splintering tension 42 inches from load.
13	do.....	12.0	360	311	7.25	8.25	.....	9.50	180	39	10	38	23.5	3,325	4,130	4.57	1.36	Splintering tension 21 inches from load.
14	Straight.....	18.1	257	311 $\frac{1}{2}$	7.25	8.25	.....	9.50	140	33	11	19	25.2	5,450	7,130	6.68	1.45	Simple tension 24 inches from load.
15	do.....	13.6	266	311	7.25	8.25	.....	9.50	143	33	13	31	27.2	2,790	3,740	5.56	1.40	Splintering tension at load.
16	do.....	36.2	412	309 $\frac{1}{2}$	7.00	9.38	.....	9.75	170	42	10	20	24.4	4,250	5,110	6.08	.94	Simple tension 12 inches from load.
17	Straight.....	18.5	255	310 $\frac{1}{2}$	7.00	8.25	.....	9.00	170	40	13	40	24.7	3,980	4,600	5.54	1.90	Simple tension 12 inches from load; brash.
18	do.....	14.3	258	311 $\frac{1}{2}$	7.25	8.88	.....	9.25	170	40	13	40	24.7	3,360	4,160	6.17	.71	Simple tension at load.
19	do.....	18.6	335	310 $\frac{1}{2}$	7.75	8.88	.....	13.50	178	38	12	21	21.6	3,400	4,160	6.17	.71	Simple tension at load.
20	Average.....	16.9	301	.....	7.50	8.74	.....	9.93	155	.....	13.5	32	25.4	4,327	5,481	6.25	.97	Simple tension 12 inches from load.
21	Maximum.....	36.2	412	.....	9.25	10.25	.....	14.75	189	42.0	19.0	60	29.3	6,130	7,480	8.72	1.62	Simple tension 12 inches from load; brash.
22	Minimum.....	11.2	250	.....	6.75	8.13	.....	8.75	97	17.0	7.0	19	21.6	2,230	2,230	4.42	.34	Simple tension at load.

1.16 Splintering tension 12 inches from load.
 Simple tension 12 inches from load.
 Splintering tension 18 inches from load.
 Splintering tension 12 inches from load.
 Longitudinal shear.
 Splintering tension 12 inches from load; brash.
 Simple tension 8 inches from load.
 Longitudinal shear.
 Simple tension at load.
 Do.
 Splintering tension 18 inches from load.
 Longitudinal shear.
 Do.
 Simple tension 24 inches from load.
 Do.
 Splintering tension 24 inches from load.
 Simple tension at load.
 Splintering tension at load.
 Do.

8.47 8.290 5.650 26.6 63 33 165 10.00 9.20 8.60 7.60 314 305 $\frac{1}{2}$ 21.8
 .81 8,050 4,840 28.4 56 34 149 8.75 8.25 7.68 7.10 266 306 $\frac{1}{2}$ 19.7
 .80 9,500 5,380 29.6 56 34 162 8.65 8.15 7.80 7.00 280 307 $\frac{1}{2}$ 19.4
 .93 7,001 5,350 28.5 42 36 163 9.00 8.50 7.65 6.75 284 313 $\frac{1}{2}$ 24.5
 .93 7,790 5,260 29.0 58 33 165 10.00 9.50 8.00 7.80 317 309 24.0
 1.13 7,190 5,760 26.0 35 39 159 10.25 9.75 8.65 7.25 317 309 24.4
 1.03 9,621 7,750 29.1 39 39 162 8.40 8.40 8.40 7.50 317 309 24.5
 .96 8,411 7,210 27.2 46 35 159 9.50 9.25 8.25 7.50 351 313 $\frac{1}{2}$ 23.8
 1.22 8,066 4,940 25.5 46 35 156 8.00 8.00 7.50 7.00 351 313 $\frac{1}{2}$ 21.8
 .86 8,896 5,920 26.7 56 36 166 9.25 9.25 8.50 7.80 351 313 $\frac{1}{2}$ 21.8
 1.10 7,835 7,920 28.4 57 36 166 8.75 8.75 7.70 7.30 351 313 $\frac{1}{2}$ 21.8
 .88 9,399 5,310 27.4 38 30 163 11.00 9.80 8.80 8.00 351 313 $\frac{1}{2}$ 21.4
 1.05 9,552 4,350 27.7 59 37 163 10.00 9.50 8.50 7.30 351 313 $\frac{1}{2}$ 21.4
 .78 7,410 4,350 26.1 59 37 163 9.80 9.25 8.40 7.80 351 313 $\frac{1}{2}$ 21.4
 .83 6,540 4,580 27.5 51 37 167 10.25 9.60 8.75 7.80 351 313 $\frac{1}{2}$ 20.4
 1.10 8,860 5,950 28.7 75 36 168 8.30 8.30 7.70 7.70 351 313 $\frac{1}{2}$ 20.4
 1.27 9,471 6,270 26.9 43 39 170 8.75 8.15 7.70 7.70 351 313 $\frac{1}{2}$ 20.4
 1.00 8,621 5,280 27.6 48 34 162 9.52 8.85 8.28 7.36 351 313 $\frac{1}{2}$ 21.9
 1.43 7,500 6,270 29.6 75 29 144 11.00 10.00 9.38 8.40 351 313 $\frac{1}{2}$ 34.8
 .69 6,335 5,190 25.5 34 29 144 8.50 8.15 7.65 6.70 351 313 $\frac{1}{2}$ 18.5

Average.....
 Maximum.....
 Minimum.....

TABLE 1.—*Results of individual tests*—Continued.
ENGELMANN SPRUCE POLES FIRE KILLED 10 YEARS.

Pole and reference No.	Grain.	Diameter at—				Approximate age.	Rings per inch.	Per cent summerwood.	Per cent sap.	Weight per cubic foot (oven dry).	Fiber stress at elastic limit.	Modulus of rupture.	Stiffness factor.	Modulus of elastic resilience.	Manner of failure.
		Top.	Center.	Load point.	Butt.										
		<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>Yrs.</i>				<i>Lbs.</i>	<i>Lbs. per sq. in.</i>	<i>Lbs. per sq. in.</i>		<i>In. lbs. per cu. in.</i>	
1	Straight.....	7.75	9.50	11.00	198	41	16	20.8	22.8	20.8	3,730	3,820	4.36	1.06	Simple tension at load.
2	Spiral.....	7.50	9.00	9.50	198	30	10	22.8	22.8	22.8	4,720	5,800	6.97	1.00	Do.
3	do.....	7.00	8.25	9.25	142	28	14	20.4	20.4	20.4	3,260	4,020	4.33	.84	Do.
4	do.....	6.75	8.25	9.25	184	44	17	26.3	26.3	26.3	3,680	4,220	6.92	.61	Do.
5	Straight.....	7.50	9.25	9.75	115	31	19	20.1	20.1	20.1	2,710	3,890	3.90	.69	Do.
6	do.....	7.00	9.00	10.50	192	34	10	23.7	23.7	23.7	5,210	6,020	6.88	1.22	Do.
7	do.....	7.00	8.75	10.50	175	30	19	23.9	23.9	23.9	4,100	5,000	6.73	.82	Do.
8	do.....	7.25	8.25	11.00	195	43	17	19.6	19.6	19.6	4,150	6,070	5.58	1.23	Simple tension 8 inches from load; brash.
9	Spiral.....	7.25	8.50	9.75	184	29	13	22.6	22.6	22.6	2,290	3,240	3.30	.56	Brittle tension 66 inches from load.
10	do.....	7.25	8.50	11.62	198	43	18	23.8	23.8	23.8	2,940	3,850	4.66	1.00	Simple tension at load.
11	do.....	7.25	9.50	11.25	198	30	15	22.9	22.9	22.9	4,100	4,350	4.66	.63	Simple tension 36 inches from load.
12	Straight.....	7.25	9.12	10.50	142	31	9	21.4	21.4	21.4	3,550	4,340	5.85	1.23	Simple tension 60 inches from load.
13	Spiral.....	7.25	9.12	10.50	142	25	15	22.4	22.4	22.4	3,110	3,720	4.42	.72	Simple tension 8 inches from load.
14	do.....	7.25	9.12	10.50	112	20	14	21.4	21.4	21.4	3,110	3,720	4.42	.72	Splintering tension 15 inches from load.
15	Straight.....	7.25	8.75	11.50	180	40	17	22.4	22.4	22.4	3,620	4,930	4.66	.96	Splintering tension 18 inches from load.
16	Spiral.....	7.25	8.75	10.75	210	34	20	20.4	20.4	20.4	2,930	3,490	3.95	.91	Simple tension 6 inches from load.
17	Straight.....	7.25	8.75	11.00	162	25	19	21.8	21.8	21.8	2,930	3,980	4.16	.69	Simple tension at load.
18	Spiral.....	7.25	8.00	10.25	155	38	13	19.3	19.3	19.3	2,180	2,180	3.56	.44	Simple tension at load.
19	do.....	7.50	9.00	11.50	190	46	24	24.1	24.1	24.1	2,950	4,220	4.21	.72	Simple tension at load.
20	do.....	8.00	9.00	10.75	120	23	14	22.3	22.3	22.3	2,600	4,340	4.08	.53	Simple tension 24 inches from load.
	Average.....	7.23	8.80	10.53	164	34.3	16	22.3	22.3	22.3	3,489	4,378	4.97	0.83	
	Maximum.....	8.00	9.75	11.63	210	46.0	24	26.3	26.3	26.3	5,210	6,070	6.97	1.25	
	Minimum.....	6.00	7.25	9.25	112	23.0	9	19.0	19.0	19.0	2,180	2,180	3.30	0.44	

POLES.

Table 1 gives the test data for individual poles.

Table 2 gives the maximum load of each pole in terms of both the equivalent pull at the top and the actual load obtained in the testing machine at the ground line. This table is of value chiefly in comparing the results of these tests with those from other methods of applying the load, as all may be reduced to the reaction at the top support for poles of the same size.

Table 3 gives a summary and comparison of the average results obtained in the tests on the four classes of poles, based on the western red cedar as 100. On a basis of fiber stress developed it will be seen that—

1. Air-seasoned lodgepole pine is superior to western red cedar in all the mechanical properties determined.

2. Fire-killed lodgepole pine is only 80 per cent as strong as western red cedar at maximum load. In elastic values, however—that is, the fiber stress at elastic limit and the work absorbed up to this point—they are practically equal. In stiffness the fire-killed lodgepole pine is quite comparable to the cedar, although the latter proved to be a more flexible wood.

3. Fire-killed Engelmann spruce was inferior in all mechanical properties to the cedar and pine.

TABLE 2.—*Top and ground-line loads required to break poles.*

Pole No.	Western red cedar, cut green and air seasoned.		Lodgepole pine, cut green and air seasoned.		Lodgepole pine fire killed 10 years.		Engelmann spruce fire killed 10 years.	
	Top reaction at maxi- mum load.	Maxi- mum load at ground line.	Top reaction at maxi- mum load.	Maxi- mum load at ground line.	Top reaction at maxi- mum load.	Maxi- mum load at ground line.	Top reaction at maxi- mum load.	Maxi- mum load at ground line.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1.....	2,020	11,600	2,185	12,580	714	4,110	1,811	10,410
2.....	1,705	9,800	1,770	10,190			1,980	11,390
3.....	2,238	12,870	1,866	10,720	1,094	6,290	1,431	8,230
4.....	2,075	11,920	2,740	15,730	1,980	11,380	1,262	7,260
5.....	1,745	10,030	1,913	11,000	2,000	11,500	1,094	6,290
6.....	2,070	11,900	2,182	12,540	1,852	10,650	2,053	11,800
7.....	2,090	12,000	1,975	11,350	2,370	13,620	2,105	12,100
8.....	1,782	10,250	2,828	16,240	1,762	10,130	2,652	15,250
9.....	1,762	10,130	2,219	12,750	1,854	10,650	1,205	6,930
10.....	2,320	13,320	1,938	11,130	1,873	10,780	1,963	11,290
11.....	1,473	8,470	2,226	12,800	2,118	12,180	1,900	10,920
12.....	2,948	16,940	2,463	14,180	2,840	16,320	2,270	13,050
13.....	2,360	13,580	2,638	15,150	2,270	13,070	1,810	10,400
14.....	1,768	10,170	1,928	11,080	2,526	14,520	1,515	8,710
15.....	2,175	12,500	2,116	12,170	1,267	7,280	2,640	15,190
16.....	1,854	10,650	3,050	17,520	2,220	12,780	1,449	8,330
17.....	2,244	12,900	1,854	10,650	1,377	7,910	1,726	9,920
18.....	2,005	11,530	2,635	15,130	1,412	8,120	731	4,210
19.....	1,935	11,120	2,395	13,770	1,369	7,870	2,058	11,820
20.....	2,440	14,030	2,445	14,050	1,822	10,480	1,850	10,620
21.....			2,148	12,340				
22.....			1,991	11,450				
Average.....	2,050	11,785	2,250	12,930	1,830	10,510	1,775	10,210
Maximum.....	2,948	16,940	3,050	17,520	2,840	16,320	2,652	15,250
Minimum.....	1,473	8,470	1,770	10,190	714	4,110	731	4,210

A comparison based on the fiber stress developed is equivalent to one based on uniform ground-line diameter. In practice, however, it is customary to specify top diameters. On a basis of measured tapers and the fiber stresses found by test, the loads may be calculated for all shipments, using a uniform top diameter of 7 inches. Table 4 gives the calculated loads for such a comparison. The tapers used in the calculations were, for western red cedar, 0.098 inch per foot length; for the air-seasoned lodgepole pine, 0.077; for fire-killed lodgepole pine, 0.096; and for fire-killed Engelmann spruce, 0.130. These tapers do not include the flare of the butt. The length from top to the load point was taken as 19.5 in all cases. Since the strength of a pole varies as the cube of its diameter, it is evident that differences in taper will materially affect the strength. On a basis of equal top diameters it will be seen from Table 4 that—

1. There is practically no difference in strength between air-seasoned lodgepole pine and western red cedar. In stiffness the lodgepole pine poles exceeded the cedar by about 25 per cent.

2. The fire-killed poles, both lodgepole pine and Engelmann spruce, were practically equal to the cedar in strength at elastic limit and about 20 per cent below it at the maximum load.

TABLE 4.—*Strength of poles compared on a basis of 7-inch tops.*

Species.	Seasoning condition.	Load at elastic limit.		Maximum load.	
		Average.	Ratio to red cedar.	Average.	Ratio to red cedar.
		<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Western red cedar.....	Cut green and air seasoned.....	7,800	100	12,000	100
Lodgepole pine.....	do.....	8,000	103	11,620	97
Do.....	Fire killed 10 years.....	7,470	96	9,500	79
Engelmann spruce.....	do.....	7,500	96	9,400	78

SMALL, CLEAR PIECES CUT FROM POLES.

Table 5 gives the results of tests on small, clear pieces in bending, compression parallel to grain, compression perpendicular to grain, and shearing. For each pole the average strength values for all pieces taken from it are given, and at the bottom of the tables are the averages of all minor tests for the species.

Table 6 gives the average strength values of minor tests summarized by species and condition of seasoning. An examination of the average results shows in general very comparable values for the fire-killed pine and spruce and for the cedar. The cedar, however, falls about 16 per cent below the pine in shearing strength and the spruce about 12 per cent below it in crushing strength. The lodgepole pine from Montana showed a bending strength nearly 40

per cent greater and a crushing strength 18 per cent greater than the fire-killed lodgepole pine. It might seem at first sight that these differences were due to deterioration on the part of the fire-killed material, but an analysis of the values in regard to weight and a comparison with values obtained from other tests on lodgepole pine indicate that deterioration is not the probable cause of the difference. It has been proved conclusively that in any species the strength of the clear wood varies directly with its dry weight.

TABLE 5.—Summary of tests on small, clear pieces cut from poles.
WESTERN RED CEDAR CUT GREEN AND AIR SEASONED.

Number of pole from which taken.	Bending.								Compression parallel to grain.						Compression per- pendicular to grain.			Shearing.		
	Number of tests.	Per cent moisture.	Weight per cubic foot (oven dry).	Per cent summer- wood.	Per cent sap.	Modulus of rupture (pounds per square inch).	Fiber stress at elastic limit (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Modulus of elastic re- silience (inch pounds per cubic inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Number of tests.	Per cent moisture.	Shear strength (pounds per square inch).
1.....	4	8.6	22.8	22	12	8,045	5,962	1,418	1.44	3	6.5	4,050	6,803	1,778	3	7.5	520	2	6.4	1,020
2.....	6	8.5	23.0	22	4	9,357	5,955	1,089	1.85	2	6.4	4,200	6,845	1,642	7	7.2	573	5	6.2	1,139
3.....	5	8.0	21.1	23	2	8,706	5,930	1,039	1.90	1	6.7	4,500	5,190	1,190	3	6.9	505	3	6.4	857
4.....	11	8.4	22.1	21	10	8,574	5,295	1,040	1.57	6	6.6	4,044	6,236	1,152	7	7.1	521	4	6.4	820
5.....	5	8.1	22.7	24	25	9,282	6,270	1,122	1.95	2	6.7	4,810	7,295	1,285	1	6.9	605	7	6.2	791
6.....	7	8.0	23.6	24	2	10,361	6,181	1,214	1.78	2	6.4	6,050	7,135	1,595	2	6.7	722	4	6.0	1,064
7.....	6	7.7	19.6	18	9	7,098	4,737	808	1.46	4	6.6	5,405	5,135	1,235	3	7.0	532	7	6.1	805
8.....	9	7.9	21.7	22	6	9,593	5,857	1,198	1.64	4	6.4	5,132	6,666	1,342	3	6.6	528	5	6.2	955
9.....	9	7.7	22.4	20	5	10,190	6,284	1,322	1.71	3	6.4	4,887	6,360	1,258	4	6.6	514	4	6.2	769
10.....	3	7.7	23.4	24	10	10,717	6,380	1,282	1.78	3	6.4	4,707	6,666	1,593	2	6.4	800	3	6.1	1,065
11.....	5	7.7	22.4	27	4	9,516	6,004	1,296	1.55	2	6.6	5,230	6,413	1,458	2	6.6	500	4	6.1	950
12.....	26	7.7	23.9	26	3	9,086	5,200	1,040	1.50	2	6.6	4,320	6,910	1,215	3	6.5	535	2	6.2	1,048
13.....	17	7.5	23.3	17	0	9,850	5,780	1,301	1.42	1	6.7	4,500	6,390	1,225	3	6.4	635	2	5.9	1,078
14.....	4	7.4	22.2	24	0	9,672	6,742	1,233	2.05	1	6.3	5,030	6,810	1,390	1	6.3	500	6	5.9	1,097
15.....	4	7.7	22.4	21	1	9,225	6,325	1,179	1.90	1	6.1	5,000	6,330	1,410	2	6.4	450	4	5.9	1,088
16.....	8	8.0	22.0	21	1	10,066	6,928	1,376	1.94	4	6.3	5,402	6,930	1,646	4	6.6	504	7	5.8	965
17.....	3	7.6	23.3	24	0	9,790	6,733	1,420	1.78	1	6.2	6,040	7,320	1,620	3	6.2	503	4	6.1	902
18.....	23	7.5	21.6	23	12	9,018	6,338	1,108	2.02	4	6.3	4,550	6,275	1,280	3	6.2	432	3	6.1	978
19.....	7	8.55	20.8	16	7	8,855	6,308	1,245	1.71	4	6.1	4,585	6,310	1,376	3	6.4	405	2	6.2	680
20.....	4	7.4	23.9	22	1	10,890	6,555	1,410	1.71	4	6.1	6,058	7,585	1,581	3	6.3	633	2	6.2	1,020
Average.....	105	7.9	22.3	22	2	9,305	5,997	1,185	1.73	156	6.4	4,825	6,540	1,373	161	6.8	538	178	6.1	959
Maximum.....	.....	9.2	25.0	30	30	12,090	7,910	1,666	2.52	.....	6.9	7,580	7,880	1,880	.....	8.8	1,000	.....	6.7	1,505
Minimum.....	.....	7.0	18.2	12	0	5,280	3,120	615	0.53	.....	5.9	1,990	4,350	640	.....	6.1	300	.....	5.4	525

1 Total.

TABLE 5.—*Summary of tests on small, clear pieces cut from poles*—Continued.
LODGEPOLE PINE CUT GREEN AND AIR SEASONED.

Number of pole from which taken.	Bending.						Compression parallel to grain.						Compression per- pendicular to grain.			Shearing.				
	Number of tests.	Per cent moisture.	Weight per cubic foot (oven dry).	Per cent summer- wood.	Per cent sap.	Modulus of rupture (pounds per square inch).	Fiber stress at elastic limit (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Modulus of elastic re- silience (inch pounds per cubic inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Number of tests.	Per cent moisture.	Crushing strength at elastic limit (pounds per square inch).	Number of tests.	Per cent moisture.	Shear strength (pounds per square inch).
1.....	2	7.7	28.2	.....	0	11,770	8,520	1,348	3.00	2	8.0	.....	6,960	.....	1	7.8	1,135	1	7.8	1,135
2.....	2	8.2	28.1	.....	0	12,680	9,112	1,520	3.04	3	8.4	.....	7,190	.....	2	8.1	992	2	8.1	992
3.....	3	8.2	31.3	.....	0	12,125	8,520	1,232	3.31	3	8.7	.....	7,023	.....	3	7.7	1,082	3	7.7	1,082
4.....	4	8.2	31.0	.....	0	14,525	11,345	1,640	4.41	3	8.3	.....	8,713	.....	3	7.8	1,093	3	7.8	1,093
5.....	5	8.0	30.3	.....	0	13,995	8,705	1,728	2.44	3	9.2	.....	8,527	.....	3	7.6	1,165	3	7.6	1,165
6.....	6	8.9	31.6	.....	0	12,700	8,400	1,410	2.78	2	8.2	.....	7,730	.....	2	8.6	1,005	2	8.6	1,005
7.....	1	10.1	34.1	.....	0	11,850	8,620	1,370	3.01	2	8.8	.....	6,810	.....	1	7.9	879	1	7.9	879
8.....	1	7.8	31.3	.....	0	15,010	10,035	1,810	3.10	2	7.8	.....	7,710	.....	0	.....	.....	0	.....	.....
9.....	2	7.4	28.8	.....	0	11,580	9,460	1,067	2.18	2	7.9	.....	5,480	.....	0	7.5	1,002	0	7.5	1,002
10.....	0	.....	.....	.....	0	.....	.....	.....	.....	2	8.2	.....	8,518	.....	1	7.6	1,248	1	7.6	1,248
11.....	2	7.6	30.9	.....	0	13,785	9,500	1,811	2.78	2	8.0	.....	8,317	.....	2	7.6	1,116	2	7.6	1,116
12.....	4	8.4	29.9	.....	0	11,825	7,954	1,413	2.52	3	8.1	.....	7,745	.....	0	.....	.....	0	.....	.....
13.....	2	8.0	29.8	.....	0	12,755	8,645	1,562	2.67	2	8.1	.....	8,295	.....	2	8.3	1,276	2	8.3	1,276
14.....	1	7.5	29.5	.....	0	11,885	7,795	1,428	2.37	3	8.2	.....	7,165	.....	1	8.2	1,002	1	8.2	1,002
15.....	2	8.6	33.0	.....	0	14,775	10,665	1,778	3.56	2	7.9	.....	8,880	.....	2	8.3	1,402	2	8.3	1,402
16.....	1	8.0	30.3	.....	0	14,480	6,500	1,985	1.18	2	8.0	.....	7,955	.....	1	8.3	1,002	1	8.3	1,002
17.....	2	8.0	30.2	.....	0	11,865	7,425	1,402	2.19	2	7.8	.....	7,228	.....	2	8.3	1,402	2	8.3	1,402
18.....	2	8.1	30.6	.....	0	13,717	9,293	1,709	2.82	2	7.9	.....	8,275	.....	1	8.2	1,103	1	8.2	1,103
19.....	2	8.4	27.3	.....	0	9,205	7,040	1,312	2.10	2	8.0	.....	6,805	.....	3	8.4	995	3	8.4	995
20.....	2	8.2	30.6	.....	25	12,265	7,580	1,412	2.26	2	8.3	.....	8,122	.....	1	8.2	1,355	1	8.2	1,355
21.....	0	.....	.....	.....	0	.....	.....	.....	.....	2	8.2	.....	8,085	.....	0	.....	.....	0	.....	.....
22.....	3	8.3	29.6	.....	0	12,890	8,520	1,408	2.97	2	8.2	.....	8,085	.....	2	8.6	1,127	2	8.6	1,127
Average.....	140	8.1	30.2	.....	0.6	12,775	8,600	1,520	2.78	153	8.2	.....	7,672	.....	135	8.0	1,129	135	8.0	1,129
Maximum.....	.....	10.1	34.5	.....	25	16,080	10,660	1,985	5.14	.....	12.2	.....	9,780	.....	.....	8.8	1,735	.....	8.8	1,735
Minimum.....	.....	7.3	26.4	.....	0	7,580	5,460	1,056	1.18	.....	7.5	.....	4,595	.....	.....	6.6	800	.....	6.6	800

LODGEPOLE PINE FIRE KILLED 10 YEARS.

1.....	2	7.7	21.6	12	6	7,402	4,820	984	1.31	2	8.2	3,395	5,050	900	4	7.4	602	2	7.3	918
2.....	2	7.6	25.0	12	6	6,525	4,550	917	1.16	1	7.9	3,810	5,940	1,090	2	7.7	799	3	7.4	1,145

3	8.2	24.8	19	7	7,400	5,097	1,224	1.18	3	8.1	4,965	5,743	1,283	3	8.4	640	0	7.6	1,242
4	7.5	26.3	13	0	7,817	5,267	1,032	1.49	8.4	5,320	6,920	5,743	1,310	0	8.1	645	2	7.7	1,995
5	7.6	25.0	12	5	9,665	5,955	1,344	1.50	8.4	4,250	5,710	5,743	1,270	0	8.5	645	1	7.7	1,995
6	7.9	28.9	22	0	9,740	6,014	1,174	1.72	8.2	4,970	7,365	5,743	1,092	1	8.5	1,092	1	7.0	1,220
7	8.1	28.1	24	6	10,720	7,777	1,429	2.37	8.1	7,200	8,635	5,743	2,010	1	8.8	1,956	1	8.0	1,795
8	7.5	24.4	20	25	9,175	6,748	1,339	1.89	7.9	4,875	5,800	5,743	1,500	3	8.3	603	0	7.5	1,115
9	7.3	24.4	16	0	7,360	5,925	1,052	1.88	8.1	5,220	6,147	5,743	1,237	3	8.3	678	0	7.5	1,115
10	7.6	24.2	17	0	10,340	6,530	1,365	1.73	0	6,738	7,360	5,743	1,690	1	8.6	525	2	7.5	1,208
11	7.7	26.4	13	10	11,755	7,300	1,542	1.92	3	8.0	6,738	7,360	1,690	1	8.6	682	2	7.5	1,208
12	8.1	25.8	17	15	9,290	4,890	1,052	1.26	2	7.8	4,138	5,555	960	1	8.3	681	4	8.1	1,236
13	7.0	28.5	17	0	8,872	6,070	1,174	1.80	0	7.8	4,002	7,365	1,695	0	7.5	766	0	7.9	1,500
14	8.0	24.4	14	25	9,690	6,580	1,145	2.10	3	8.1	4,667	5,700	1,280	0	8.2	616	1	7.6	1,282
15	8.0	26.2	18	0	10,455	6,778	1,364	1.88	3	8.4	5,645	6,670	1,430	3	8.8	781	0	7.6	1,282
16	8.3	27.7	18	4	10,340	7,050	1,460	1.89	2	8.4	5,970	6,663	1,380	4	8.9	910	0	7.6	1,282
17	8.6	25.6	15	0	7,660	6,770	1,015	2.50	2	8.6	4,170	5,095	1,230	2	8.4	571	1	7.6	1,150
18	8.4	25.6	18	0	8,830	7,110	1,268	2.22	2	8.3	6,160	7,105	1,480	2	8.2	948	2	8.0	1,200
19	8.3	27.0	18	0	9,460	7,610	1,365	2.36	2	8.8	6,295	7,565	1,465	1	8.0	975	1	8.2	1,185
20	7.8	25.9	17	3	9,049	6,145	1,217	1.75	137	8.2	5,278	6,486	1,361	142	8.3	740	128	7.7	1,148
Average...	8.6	30.3	25	23	12,350	8,310	1,622	2.68	-----	9.3	7,200	8,770	2,010	-----	10.0	1,210	-----	10.2	1,500
Maximum...	8.6	30.3	25	23	12,350	8,310	1,622	2.68	-----	9.3	7,200	8,770	2,010	-----	10.0	1,210	-----	10.2	1,500
Minimum...	6.6	21.5	10	0	5,130	3,280	822	0.73	-----	7.4	3,000	4,560	890	-----	6.8	402	-----	6.3	680

ENGELMANN SPRUCE FIRE KILLED 10 YEARS.

1	8.0	22.4	24	0	7,192	5,580	1,154	1.50	4	8.2	4,878	5,690	1,290	4	8.0	632	1	8.5	905
2	8.1	21.8	15	0	7,860	4,260	1,071	1.94	2	7.8	4,370	5,360	1,290	3	8.5	580	1	8.0	835
3	8.0	20.6	21	0	7,170	5,630	923	1.92	3	7.8	3,370	4,740	1,018	3	8.2	580	1	8.4	840
4	7.7	27.9	18	0	10,860	7,048	1,560	1.85	0	7.8	4,370	5,360	1,290	1	8.2	765	1	8.7	1,390
5	8.0	22.6	18	0	7,308	5,655	1,149	1.54	1	7.8	4,370	5,360	1,290	1	8.2	600	1	8.4	1,050
6	7.5	23.4	14	0	10,282	7,149	1,376	2.08	3	7.6	5,025	4,800	1,140	3	8.2	604	0	8.1	1,132
7	8.0	22.9	12	0	10,342	6,839	1,297	2.01	1	8.0	5,250	5,780	1,535	3	8.3	681	1	7.7	1,325
8	8.1	25.8	18	0	10,940	8,038	1,528	2.34	2	8.2	5,600	6,395	1,250	3	8.4	834	1	7.3	1,200
9	8.1	21.4	15	0	7,925	5,295	1,041	1.51	0	7.9	4,680	5,120	1,080	3	8.5	526	2	8.0	972
10	7.8	23.1	17	0	8,970	5,926	1,138	1.78	1	7.5	4,560	5,230	1,180	3	8.1	900	2	8.0	1,035
11	7.8	25.0	16	0	9,857	6,337	1,117	1.58	0	7.6	6,750	6,825	1,610	4	7.4	839	2	8.2	1,210
12	7.8	25.0	16	0	8,490	5,910	1,117	1.77	2	7.9	4,783	5,567	1,147	4	7.6	596	3	7.8	1,323
13	7.8	21.5	14	0	8,198	5,538	1,078	1.62	2	7.9	4,605	5,405	1,210	2	7.7	638	3	7.9	1,178
14	8.2	22.0	17	0	8,087	5,197	1,002	1.55	2	7.7	4,870	5,660	1,040	5	7.8	629	5	7.8	1,102
15	8.4	25.7	24	0	8,668	5,625	1,098	1.60	2	7.7	4,412	6,205	1,461	2	8.2	552	2	8.2	1,208
16	8.0	25.1	21	0	11,277	7,192	1,383	2.08	0	7.7	4,412	6,205	1,461	3	8.1	503	2	8.5	1,370
17	8.0	25.1	21	0	8,162	6,027	1,002	2.03	0	8.2	4,430	5,445	907	2	7.8	418	3	8.1	1,945
18	8.1	21.7	13	0	9,045	6,103	1,194	1.80	4	8.2	4,430	5,445	907	5	7.8	736	3	7.3	1,292
19	8.0	23.3	17	0	12,360	9,100	1,620	3.00	4	7.9	4,585	5,696	1,208	154	8.0	621	2	7.9	1,142
20	7.1	19.8	10	0	6,650	4,260	850	.87	-----	7.3	2,030	4,650	740	-----	6.2	377	-----	6.1	555
Average...	8.0	23.3	17	0	9,045	6,103	1,194	1.80	135	7.9	4,585	5,696	1,208	154	8.0	621	140	7.9	1,142
Maximum...	8.8	28.3	25	0	12,360	9,100	1,620	3.00	-----	9.0	4,585	5,696	1,208	-----	8.9	995	-----	8.9	1,585
Minimum...	7.1	19.8	10	0	6,650	4,260	850	.87	-----	7.3	2,030	4,650	740	-----	6.2	377	-----	6.1	555

1 Total.

TABLE 6. Results of tests on small, clear specimens cut from poles, summarized by species and condition of seasoning.

Species and condition of pole from which cut.	Bending.					Compression parallel to grain.				Compression perpendicular to grain.		Shearing.				
	Num-ber of tests.	Per cent mois-ture.	Rings per in-ch.	Weight per cubic foot (oven-dry).	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Modulus of elastic resilience.	Num-ber of tests.	Crushing strength at elastic limit.	Modulus of elasticity.	Maxi-mum crushing strength.	Num-ber of tests.	Crushing strength at elastic limit.	Num-ber of tests.	Shearing strength.
Western red cedar: Cut green and air seasoned—																
				Pounds.	Pounds per square inch.	Pounds per square inch.	1,000 pounds per square inch.	Inch pounds per cubic inch.			1,000 pounds per square inch.	Pounds per square inch.		Pounds per square inch.		Pounds per square inch.
	105	7.9	16.9	22.3	5,987	9,305	1,185	1.73	56	4,825	1,373	6,540	61	538	78	959
	Maximum.....	9.2	29.0	25.0	7,910	12,090	1,666	2.52	.....	7,580	1,880	7,880	.....	1,000	.....	1,505
Minimum.....	.....	7.0	6.0	18.2	3,120	5,280	615	0.53	.....	1,990	640	4,350	.....	300	.....	525
Lodgepole pine: Cut green and air seasoned—																
	40	8.1	31.9	30.2	8,600	12,775	1,520	2.78	53	.....	.....	7,672	.....	.....	35	1,129
	Maximum.....	10.1	49.0	34.5	10,660	16,080	1,985	5.14	.....	.....	.....	9,780	.....	.....	.....	1,735
Minimum.....	.....	7.3	12.0	26.4	5,460	7,580	1,056	1.18	.....	.....	.....	4,595	.....	.....	.....	800
Fire killed 10 years—																
	41	7.8	26.1	25.9	6,145	9,049	1,217	1.75	37	5,278	1,361	6,486	42	740	28	1,148
	Maximum.....	8.6	56.0	30.3	8,310	12,350	1,622	2.68	.....	7,200	2,010	8,770	.....	1,210	.....	1,500
Minimum.....	.....	6.6	13.0	21.5	3,280	5,190	822	0.73	.....	3,000	890	4,560	.....	402	.....	660
Engelmann spruce: Fire killed 10 years—																
	54	8.0	35.1	23.3	6,163	9,045	1,194	1.80	35	4,585	1,208	5,696	54	621	40	1,142
	Maximum.....	8.8	66.0	28.3	9,100	12,360	1,620	3.00	.....	6,750	1,700	7,000	.....	995	.....	1,595
Minimum.....	.....	7.1	19.0	19.8	4,260	6,050	850	0.87	.....	2,030	840	4,650	.....	377	.....	555

In figure 7 the weight-strength relations are plotted for bending tests on small specimens cut from the tested lodgepole pine poles and for similar specimens taken from other material grown in Colorado and Wyoming, cut green and air seasoned. It will be seen that fire-killed lodgepole pine is equal in strength to the Colorado and Wyoming material cut green and air seasoned, and that the Montana material gave higher strength values because it was exceptionally heavy and much above the normal for Colorado-grown timber of which the fire-killed poles were representative. The soundness of

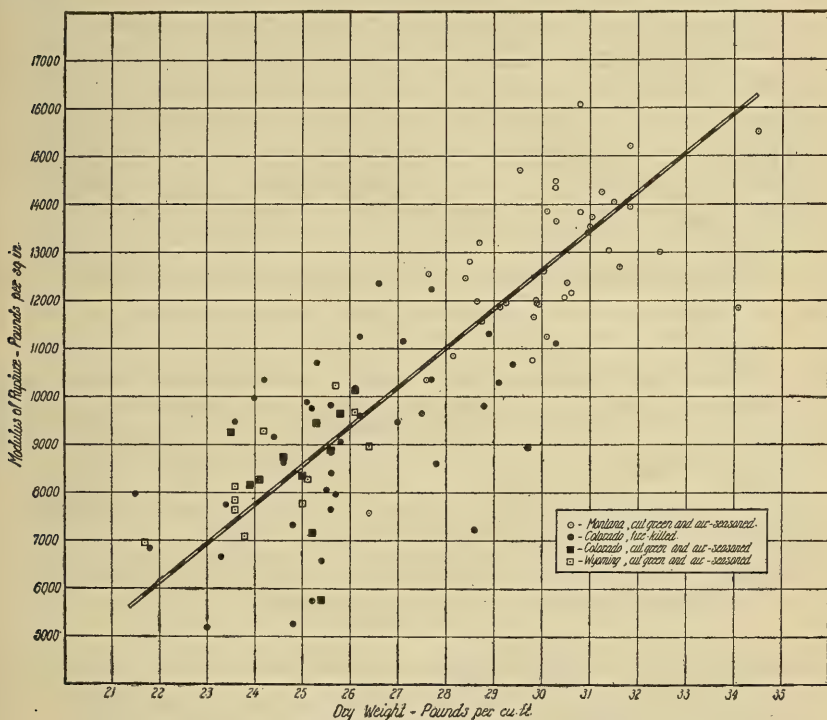
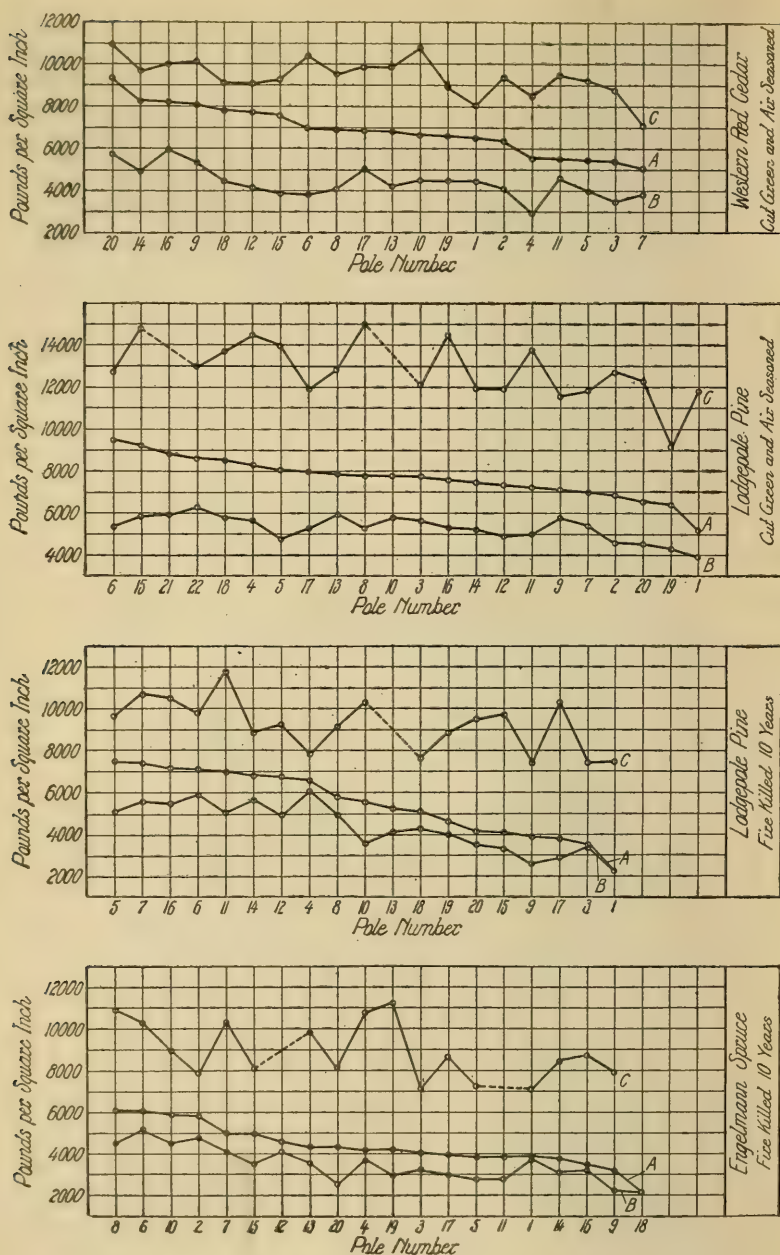


FIG. 7.—Weight-strength relations for clear, dry lodgepole pine.

the sticks cut from the fire-killed material also indicates that such timber has no inherent defect due to having been killed by fire. It seems more reasonable to regard it simply as seasoned wood, and to assume that deterioration due to age or exposure, if present, would be indicated by the same signs of decay that are apparent in any unsound material.

The relation between the stresses shown by the individual poles and those shown by the minor tests on the material cut from them is presented in figure 8. It should be remembered that the moisture content of the small specimens was only 8 per cent, as compared with an average of about 16 per cent for the poles. The green-cut



Legend -

- A - Modulus of Rupture for poles*
- B - Fiber Stress at Elastic Limit for poles*
- C - Modulus of Rupture for small clear beams cut from tested poles*

FIG. 8.—Relation of fiber stress of poles and modulus of rupture of small, clear beams cut from them to the modulus of rupture of poles.

lodgepole pine shipment averaged about 22 per cent moisture, though the outer shell of the poles was somewhat drier (see fig. 3). This would tend to make the difference between the strength of the poles and the actual strength of the material in it much greater than was the case. The curve given on page 10 of Forest Service Circular 108, *The Strength of Wood as Influenced by Moisture*, shows that, for eastern spruce, strength in bending will be reduced by about 30 per cent when the moisture content is increased from 8 per cent to 16 per cent. Tests on lodgepole pine from Wyoming indicate a reduction, under similar circumstances, of about 25 per cent. The curves shown in figure 8 have, however, been plotted with the values as obtained from the tests.

The curves, arranged in order of the modulus of rupture of the poles from highest to lowest, show the relation between the modulus of rupture of the small, clear sticks and the fiber stress of the poles at the elastic limit and maximum load. The position and number of checks, knots, and other defects, rather than the quality of the clear wood, determines the grade of a pole. While the curve for the modulus of rupture of the small pieces is erratic, as would be expected from the rather small number of tests averaged for each pole, it shows a tendency to fall with a fall in strength of the poles, indicating the influence of the quality of the clear wood on the strength of the poles. The most important relation shown by the curves is that the ratios between pole and minor strengths are not the same for the different species, indicating that it is not safe to compare species for use as poles on the basis of the strength of their clear material. For example, western red cedar gave an average modulus of rupture for the small, clear beams of 9,305 pounds per square inch, and the lodgepole pine from Montana averaged 12,775. While the strength of the clear material of the pine is thus 37 per cent higher than that of the cedar, the average strength of the poles was a little less than 12 per cent higher. The ratios of the average modulus of rupture of the poles to that of the clear material for two conditions of moisture is as follows:

Kind of poles.	As tested at 8 per cent.	As esti- mated ¹ at 16 per cent.
Western red cedar.....	0.74	0.98
Lodgepole pine:		
Green cut.....	.60	.80
Fire killed.....	.60	.80
Engelmann spruce, fire killed.....	.48	.65

¹ On the basis that an increase in moisture from 8 to 16 per cent causes a 25 per cent reduction in strength.

CONCLUSIONS.

The tests on poles and specimens cut from them show that—

1. Air-seasoned lodgepole pine poles cut from live timber in Montana were fully equal in strength to the cedar poles tested. In actual stress developed they were superior, but on account of the greater taper of the cedar poles this advantage was lost in a comparison based on equal top diameters, the dimension usually specified.

2. Cedar poles were superior to the pine and spruce poles cut from a fire-killed area in Colorado in maximum load developed. The three shipments were, however, practically equal at the elastic limit. Were the native poles to be used in place of cedar without change of specifications, it would follow that the factor of safety would be reduced one-fifth for conditions at failure, but would remain the same for stresses at the elastic limit.

3. The fire-killed pine, after standing 10 years, did not show deterioration to any appreciable extent when compared to seasoned lodgepole pine cut from representative live trees in Wyoming and Colorado. The advantage in strength of the material from the lodgepole pine poles from Montana can be accounted for by the fact that it was above normal in weight—at least for lodgepole pine from the southern part of its range.

4. The ratio between the strength of the poles and the strength of the clear material cut from them is not constant for the different kinds of wood. This "efficiency" factor varied from 0.74 to 0.48 of the strength of the clear wood when the comparison is made as tested, and from 0.98 to 0.65 when compared on the basis of values estimated to represent the same moisture condition in the small pieces as existed in the poles when tested. The values were highest for the cedar and lowest for the spruce, the pine representing an average for the three species.

POLE TESTS BY THE PACIFIC TELEPHONE & TELEGRAPH CO.

The Pacific Telephone & Telegraph Co. made tests on 81 poles of western red cedar and Port Orford cedar at the pole yards of the Western Electric Co. near Richmond, Cal. These poles were 25 and 30 feet in length, with 6, 7, and 8 inch top diameters, and 35 feet in length, with 7, 8, and 9 inch tops.

The method employed in these tests makes it impossible to make any accurate comparisons of stress values with those obtained in the Forest Service tests. In the telephone company's tests stresses are figured for the point of failure, while the Forest Service tests are figured for the load point or ground line, theoretically the point of greatest stress.

In the telephone company's tests the poles were tested horizontally, with 6 feet of the butt end of the pole held firmly between four 12

by 12 inch posts set in the ground. The load was applied to the top of the pole, by means of a winch, at a rate of 1 foot per minute. A direct-reading dynamometer was placed in the line connecting the winch with the top of the pole. The top end of the pole was supported on a dolly with truck casters which traveled on a piece of sheet iron, thus eliminating friction. Readings of the movement of a nail driven into the top of the pole were taken for each 100 pounds increment of load.

The Pacific Telephone & Telegraph Co. has kindly permitted the use of their test data, and Table 7 is compiled from their report. Comparison of the equivalent top load in Table 2 with the top load for 7-inch by 25-foot poles in Table 7 shows a difference of only 5 per cent, while the calculated stresses are about 20 per cent greater for the Forest Service results. This difference, as already stated, is probably due to the different methods used, both for calculating the stress and for supporting the butt of the pole.

Reference to Table 7 shows that there is no consistent variation when poles of the same top diameter but of different lengths are compared. However, Table 8, compiled from Table 7, shows a very marked relation between top diameter and top breaking load in the three classes of poles tested by the Pacific Telephone & Telegraph Co.

TABLE 7.—*Results of pole tests made by the Pacific Telephone & Telegraph Co.*

WESTERN RED CEDAR FROM IDAHO.

Top diameter.	Length.	Number of poles tested.	Average values of—						
			Weight of poles.	Weight per cubic foot.	Moisture.	Rings per inch.	Sap.	Top load at failure.	Modulus of rupture.
<i>Inches.</i>	<i>Feet.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Pounds.</i>	<i>Lbs. per sq. in.</i>
6	25	3	205	22.0	9.4	13.7	38.0	1,853	6,221
7	25	4	244	23.0	9.2	23.0	27.6	1,948	5,712
8	25	3	282	22.9	10.2	18.3	26.3	2,667	5,290
6	30	4	283	22.4	13.6	20.1	28.1	1,590	5,126
7	30	4	344	26.1	10.0	23.3	24.5	2,434	5,549
8	30	3	382	23.4	9.1	23.4	21.4	2,740	5,308
7	35	3	477	22.1	8.1	19.3	40.8	2,000	5,080
8	35	3	471	19.4	10.4	18.5	25.7	2,125	4,391
9	35	3	522	21.5	10.2	22.6	24.9	2,992	4,755

WESTERN RED CEDAR FROM OREGON AND WASHINGTON.

6	25	3	204	24.1	8.7	24.4	41.6	1,470	5,525
7	25	3	213	19.8	15.1	6.6	41.2	1,625	4,481
8	25	3	238	19.8	18.0	9.5	30.1	2,072	4,816
6	30	3	255	21.7	17.0	7.2	36.8	1,352	5,784
7	30	3	240	18.8	7.4	9.3	33.3	1,597	7,006
8	30	3	395	22.8	15.4	11.3	29.2	2,385	3,146
7	35	3	331	21.1	9.2	8.0	32.7	1,712	6,408
8	35	3	546	24.6	34.0	6.8	38.2	1,888	4,349
9	35	3	597	24.8	11.6	24.3	17.4	3,257	5,665

TABLE 7.—*Results of pole tests made by the Pacific Telephone & Telegraph Co.—Contd.*

PORT ORFORD CEDAR.

Top diameter.	Length.	Number of poles tested.	Average values of—						
			Weight of poles.	Weight per cubic foot.	Moisture.	Rings per inch.	Sap.	Top load at failure.	Modulus of rupture.
<i>Inches.</i>	<i>Feet.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Pounds.</i>	<i>Lbs. per sq. in.</i>
6	25	3	256	31.3	11.6	16.3	.....	2,027	7,616
7	25	3	315	24.8	10.7	25.6	.....	3,277	7,896
8	25	4	460	26.6	13.3	10.3	.....	3,740	6,058
6	30	3	375	24.3	8.6	15.3	.....	2,518	6,817
7	30	3	397	25.2	20.5	15.0	.....	2,790	7,332
8	30	3	441	24.0	9.6	14.7	.....	3,577	7,824
7	35	3	585	30.4	10.1	9.0	.....	3,123	6,851
8	35	3	591	28.1	9.7	21.0	.....	3,057	6,928

TABLE 8.—*Relation between top diameters and top breaking loads.*

[Pacific Telephone & Telegraph Co.'s tests.]

Length of poles.	Top diameter.	Western red cedar from Idaho.		Western red cedar from Oregon and Washington.		Port Orford cedar.	
		Number of poles.	Average top breaking load.	Number of poles.	Average top breaking load.	Number of poles.	Average top breaking load.
	<i>Inches.</i>		<i>Pounds.</i>		<i>Pounds.</i>		<i>Pounds.</i>
25 and 30 feet.....	6	7	1,703	6	1,411	6	2,272
25, 30, and 35 feet.....	7	11	2,139	9	1,645	9	3,063
25, 30, and 35 feet.....	8	9	2,511	9	2,115	11	3,169
35 feet.....	9	3	2,992	3	3,257		

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PASTURE AND GRAIN CROPS FOR HOGS IN THE PACIFIC NORTHWEST.

By BYRON HUNTER, *Agriculturist, Office of Farm Management.*¹

INTRODUCTION.

This bulletin deals specifically with crops and systems of cropping that may be used in economical pork production in the Pacific Northwest. Scattered here and there throughout the Northwest are men who are successfully producing pork. They have been visited, and their methods, crops, and feeding systems have been studied. This bulletin makes the practices of these successful men available to all.

Owing to the rapid growth in population of this section during the last decade, the demand for pork has increased faster than the supply, and there is little reason why hog raising should not become a more important industry in the Pacific Northwest. Although there have been some outbreaks of hog cholera, the Northwest has been remarkably free from this disease. The larger cities have well-equipped packing houses, and modern union stockyards are in operation at Portland, Oreg. During recent years a large percentage of the hogs slaughtered in the cities of Portland, Tacoma, Seattle, and Spokane have been shipped from east of the Rocky Mountains. In addition to this, enormous quantities of eastern bacon and lard are annually consumed by the Pacific Coast States.

MANAGEMENT OF PASTURES.

Since economical pork production depends largely upon the consumption of a great deal of cheaply grown feed, the pasture should be so managed that the forage produced will be clean, tender, and palatable. In practice, hog pastures are generally managed in one of three ways: (1) Continuous close grazing, (2) alternate pasturing of equal areas, and (3) pasturing the meadow.

NOTE.—This publication is intended to encourage hog raising in the Pacific Northwest; it is especially adapted to Washington, Oregon, and Idaho.

¹ Mr. Hunter is now State leader in charge of Farm-Management Field Studies and Demonstrations in the State of Washington, and is employed cooperatively by the United States Department of Agriculture and the State College of Washington.

CONTINUOUS CLOSE GRAZING.

The method in most common use is to turn in all the hogs the pasture will support, leaving them in the field during the entire season. Usually the pasture is kept closely grazed. Too often it is overgrazed, the plants being cropped so closely that the stand is soon ruined. The pasture then becomes little better than a dry lot, and the hogs make unsatisfactory gains. When the feed in the pasture becomes scarce, either the number of hogs per acre should be reduced or other forage provided.

ALTERNATE PASTURING OF EQUAL AREAS.

One of the most satisfactory ways of managing a pasture is to divide it into two or more fields of equal area. These fields are then used alternately, the hogs remaining in each about a week or 10 days. In the case of clover and alfalfa the growth is allowed to become 3 to 4 inches high before the hogs are turned in to eat it off quickly. When the pasture consists of such crops as rape, kale, and vetch, which will not stand close grazing, the growth is permitted to reach a height of 8 or 10 inches before the hogs are turned in.

Changing the hogs from field to field gives the pasture a period of rest, during which the plants recuperate and grow rapidly. When the stock is returned to the field the forage is clean, tender, and palatable and large quantities are consumed. Owing to the rapid growth made while at rest, a pasture that is subdivided and the areas grazed alternately is capable of carrying a much larger number of hogs per acre, other conditions being equal, than one that is continuously pastured.

Hogs usually graze a pasture somewhat unevenly, some areas being eaten off much more closely than others. To keep down the weeds and make the growth come on evenly, the pasture is clipped with a mower immediately after the hogs are removed. Hogs are inclined to root when the surface of the ground is wet or damp. For this reason the pasture, if under irrigation, is irrigated just after the hogs are changed from one pasture lot to the next. This gives the surface of the ground time to dry before the forage is large enough to be grazed.

PASTURING THE MEADOW.

Many successful hog raisers prefer to use such crops as clover and alfalfa for both pasture and hay at the same time. The number of hogs turned into the field is so limited that the usual crops of hay are made. The chief advantages of this method are (1) the presence of an abundance of feed, (2) the meadow is not grazed closely enough for the stand to be injured, (3) it is not necessary to subdivide the pasture into smaller areas for alternate pasturing, and (4) the changing of the hogs from one inclosure to another is obviated.

When the number of animals pastured is so limited that the usual hay crops are made, the growth becomes so coarse and woody that they do not consume as much forage as is desirable for economical gains, as the hogs relish the young shoots best. When the forage becomes too large to furnish desirable feed, an area near the watering place is clipped with a mower. This should be large enough to furnish the desired amount of pasture. In a few days the clipped area produces a vigorous growth of new shoots, upon which the hogs feed without materially disturbing the rest of the meadow. If the area first mowed is not sufficient to furnish the required feed, more of the meadow is clipped, as necessity may demand. To prevent the



FIG. 1.—Hogs on alfalfa pasture without other feed. Note their thin condition and ungainly shape, especially the older hog on the left.

stand of these clipped areas from becoming injured by overgrazing, different portions of the meadow are used in this way from year to year.

GRAIN RATION WHILE HOGS ARE ON PASTURE.

While the cost of producing pork may be reduced materially by the use of such roughage as alfalfa hay, roots, or green-pasture forage, it is desirable to feed grain or other concentrated feed in addition. Mature, dry brood sows are sometimes maintained in an apparently satisfactory condition on good pasture alone. Young growing hogs, on the other hand, usually become ungainly in shape, big bellied, and thin in flesh or stunted when compelled to subsist on pasture alone. Figure 1 illustrates the condition of hogs run on pasture without other feed.

Hog growers differ quite widely regarding the quantity of grain that should be fed while on pasture. Some feed a full grain ration, i. e., all the grain the hog will consume. Others feed a medium ration, one that is equal to about 2 to 3 per cent of the live weight of the hog. Still others prefer a light grain ration, one that is equal to only about 1 per cent of the live weight of the hog. Occasionally men are found who run young shoters on pasture without other feed. This is a mistake, for it almost invariably results in a stunted hog. No fixed and fast rule can be laid down, for the supplemental grain ration which should be fed in conjunction with green pasture depends upon a number of factors, the more important of which are (1) the age at which the hogs are to be marketed, (2) the price of grain, and (3) the plentifulness and quality of the pasture.

RATIONS FOR HOGS OF VARIOUS CONDITIONS AND MARKET AGES.

If hogs are to be marketed when 7 to 9 months old, it is necessary to feed them about all the grain they will consume, in addition to the pasture, in order to make them reach the weight demanded by the market, 170 to 225 pounds. Hogs that are marketed when 10 to 12 months old are usually maintained on pasture alone during the grazing season. If fed at all, the grain ration is very light. This results in a slow daily gain, but a greater percentage of the growth is made from the cheaply grown forage. The added cost of maintaining a hog until 10 to 12 months old, however, usually more than equals the saving of the grain ration.

Mature breeding stock that is not expected to make any gain in weight requires but little, if any, additional feed when on good pasture. Hogs that are thin in flesh and nearly grown may be expected to make small daily gains without other feed when on the best of pasture. Pigs and small shoters usually become stunted when on pasture unless given a liberal quantity of additional feed. Young hogs should be so fed that they grow rapidly instead of becoming stunted. During the fattening period, hogs on pasture should be fed all the grain they will eat up clean three times a day.

THE PRICE OF GRAIN.

Owing to the fluctuation in the price of hogs and of grain, the supplemental grain ration is sometimes expensive. Under such circumstances there is great temptation to place the hogs upon an exclusive pasture ration. This seldom pays, for it usually takes approximately as much concentrated feed in the end, and much more time, to fit for market hogs which have been on an exclusive pasture diet as is required for hogs fed liberally while on pasture. Under extreme circumstances mature breeding stock or hogs which are nearly grown may be carried on good pasture until cheaper concentrated feed can be obtained.

QUALITY AND ABUNDANCE OF PASTURE.

The composition of pasture forage is quite variable. Alfalfa, clover, vetch, peas, etc., furnish feed that is much richer in protein than most other crops. Generally, therefore, hogs which are feeding upon leguminous pasture require slightly less concentrated feed than when grazing upon nonleguminous pasture, such as timothy, orchard grass, bluegrass, or the cereals.

It frequently happens that a farmer has more hogs than his pasture is capable of supporting. When such is the case the pasture will go much farther if a full grain ration is fed. The more grain a hog consumes the less he will feed upon the pasture.

In general, pigs and shotes should be kept in a thrifty, growing condition at all times. It never pays to allow them to cease growing



FIG. 2.—A herd of brood sows on pasture. They were fed enough grain to keep them in good condition.

and become stunted. Brood sows, likewise, must be kept in good flesh (not fat) if large litters of strong, healthy pigs are to be expected. Figure 2 shows a herd of well-kept brood sows on pasture.

In gathering the material for this bulletin it was quite generally observed, on the one hand, that the men who are enthusiastic pork producers feed a liberal supplemental grain ration to young, growing hogs when on pasture. On the other hand, those who think there is little profit in raising hogs run them very largely on pasture without other feed during the grazing season.

HOGGING OFF CROPS.

Turning hogs into a standing field of mature or nearly mature wheat, barley, peas, or corn and allowing them to feed at will until the crop is consumed is called "hogging off" or "hogging down" the

crop. To some this may appear to be a wasteful practice. Under good management, however, it is a very satisfactory and economical method of utilizing limited areas of these crops.

ADVANTAGES IN HOGGING OFF CROPS.

Some of the advantages in hogging off crops are (1) the cost of harvesting and marketing the crop is saved, (2) the labor of caring for hogs is greatly reduced, (3) the vegetable matter in the soil is increased, (4) the droppings of the animals are distributed quite evenly, and (5) the hogs are given exercise. It costs from 15 to 25 cents per bushel to harvest and market wheat in the greater part of the wheat belt of the Pacific Northwest, the cost varying with the yield, the method of harvesting and thrashing, and the distance the wheat is hauled to market. In some of the more arid wheat-growing districts of both Oregon and Washington the yield of wheat is frequently as low as 6 to 8 bushels per acre. The cost of harvesting and marketing such crops runs from 35 to 40 cents per bushel. The cost of harvesting and marketing barley is approximately the same as that of wheat. When the hogs are so managed that the crop is thoroughly cleaned up, hogging off the crop practically saves the cost of harvesting and marketing. In the case of light-yielding crops this saving is considerable.

Most of the crops that are suitable for hogging off are utilized during the busiest season of the year, i. e., at a time when it is very desirable that the hogs require as little attention as possible. If turned into a mature field of wheat, peas, or corn and provided with water, shade, and salt, the hogs require very little other attention.

Most of the arable lands of the Pacific Northwest would be materially benefited by the addition of more organic matter. When the crop is hogged off, the straw, pea vines, or cornstalks, as the case may be, are left on the ground. By cutting this material thoroughly in the fall of the year with a sharp disk harrow and plowing it under, the soil is enriched in vegetable matter. This, in turn, greatly reduces the tendency of the soil to wash. The washing of soil due to the burning of straw and consequent lack of humus is well shown in figure 3.

In hogging off the crop, the droppings of the animals are scattered quite evenly over the field.

USUAL GRAIN CROPS HOGGED OFF.

The Pacific Northwest is peculiarly adapted to the hogging off of crops. The wet season occurs during the winter months and the dry season during the summer. This gives a long period in which crops may be used in this way. The principal crops that are suitable for hogging down are wheat, field peas, corn, and barley.

Wheat.—Wheat is generally used from the time the first spots in the field are nearly ripe, about the stiff-dough stage, until the stubble field is open or until field peas or some other crops are ready for use. It will be seen, then, that the season for using wheat is from four to six weeks. If used during a longer period, there may be considerable loss from shattering, and the autumn rains in some localities may also damage the crop.

A soft variety of wheat with a smooth club type of head is best suited for hogging down. The club head does not shatter so readily as most other types. The true hard and bearded varieties, such as Turkey, are not suitable. The kernels become so hard and the beards are so severe on the hogs' mouths that they do not eat enough to make economical gains.



FIG. 3.—Soil washing near Dayton, Wash., in the spring of 1910. This land was summer-fallowed during the season of 1909 and planted to winter wheat.

On the farm of W. H. Steen, Umatilla County, Oreg., 90 hogs pastured from July 17 to August 24 on 11 acres of ripe standing wheat, estimated to yield 15 bushels per acre, made an average gain in weight of 160 pounds per acre, worth \$14.40. In another instance M. E. Schreck, of Whitman County, Wash., pastured 109 head of hogs on $7\frac{3}{16}$ acres of standing wheat and 1 acre of pasture from July 30 to August 17. The hogs made a gain of 212 pounds per acre and gave a net value per acre of \$15.73. The net returns from 44 acres of wheat alongside, yielding $19\frac{1}{4}$ bushels per acre, were only \$8.04 per acre.

Field peas.—The field pea is one of the most satisfactory crops to harvest with hogs. The quality of feed furnished is of the very best, hogs are very fond of the mature peas, and under good management

the crop is gathered with but very little waste. Most varieties of peas are comparatively large and difficult to cover. What is shattered usually lies on the surface of the ground until picked up later.

The hogs are turned into the field about the time the last peas are nearly mature. In most districts they may be used until about October 1, or until there is danger of the crop being damaged by wet weather. A protracted autumn rain falling upon a heavy crop that the hogs have not cleaned up may cause the peas to sprout. To prevent this the vines are sometimes burned as soon after the rain as they are dry enough. Burning the vines leaves the peas lying upon the surface of the ground. It is not necessary to burn the vines, however, if a movable fence is used and the hogs are made to clean up the crop in small areas that will last from two to three weeks each. Since ripe, mature peas are rich in protein, green succulent feed in addition to the peas will help to balance the ration.

Corn.—Where corn is successfully grown it is an excellent crop to hog down. Carefully conducted tests at the Minnesota experiment station show that hogs waste no more corn in the field than when fed in lots, and that they gather it as clean as most men do in husking.¹ Farm experience also bears out this conclusion. Corn is advantageously used from the time the ears are well glazed until the weather becomes unfavorable and the ground muddy. In some districts of the Northwest, where the rainfall is scant, corn can be hogged off far into the winter. There is slightly less waste if a movable fence is used and the hogs are not turned into more corn than they can consume in 15 or 20 days. Especially is this true when the ground becomes wet and muddy.

Barley.—As a crop to hog off, barley is used during the summer, autumn, and winter. Because the beards, when dry and hard, are so severe on the mouth of the hog, the common beardless barley is generally used during the summer and early autumn. The bearded varieties usually outyield the beardless considerably, and for this reason the former are generally preferred for late autumn and winter use. There are some, however, who prefer the beardless varieties for all seasons.

If sown very early in the spring, beardless barley generally ripens about ten days or two weeks earlier than winter wheat. This makes it one of the first crops available for hogging off in the early summer. The hogs are turned into the field when the first patches are ripening, or when the kernels are in the stiff-dough stage.

Hogs do only fairly well on mature bearded barley when the beards are dry and stiff. After the autumn rains have softened the beards and kernels, however, they take to it readily. For late autumn and

¹ Gaumnitz, D. A., Wilson, A. D., and Bassett, L. B. Pork production. Minnesota Agricultural Experiment Station, Bulletin 104, p. 63-119, 9 fig., 1907.

winter use the bearded varieties are allowed to stand in the field until the fall rains have set in well. This usually gives plenty of time after harvest for the hogs to glean the stubble field. Blue barley, a bearded variety, is generally sown for late fall and winter use. When allowed to stand in the field it does not shatter and sprout nearly so easily as wheat or the so-called winter varieties of barley.

On a farm in Umatilla County, Oreg., during November, 1910, 80 hogs were pastured 18 days and 98 hogs 10 days on 11.4 acres of barley on a steep hillside. The gain in weight averaged 230 pounds per acre, having a value of \$18.35 per acre. The estimated yield of



FIG. 4.—A hillside on the farm of W. H. Steen, Umatilla County, Oreg., too steep for the use of a binder, but satisfactorily harvested by hogs. The shotes in the picture are gleaning the barley after the fattening hogs have taken the greater part of the feed.

barley was 21 bushels per acre. Figure 4 shows the hillside with shotes gleaning the barley after the fattening hogs have taken off practically all the feed.

DETERMINING THE AREA TO BE HOGGED OFF.

In order to reduce the waste to a minimum, the area of each crop hogged off must be thoroughly cleaned up. Owing to the variation in crop yields and the quantity of grain that hogs of different sizes will consume, it is not always easy to determine the acreage of each crop to be used in this way. Suppose a portion of the main winter-wheat crop is to be fenced and hogged off from the time the grain is just past the stiff-dough stage, say July 10, until the stubble field is open, August 15. What area of the winter wheat shall be set aside

to be used in this way? This may be determined in two ways, as follows:

(1) When the first spots in the field are nearly ripe or when the kernels have just passed the stiff-dough stage, measure and fence a small trial area, enough to last the herd of hogs for only a few days. From July 10 to August 15 is 36 days. If a trial area of one acre lasts the herd 6 days, as many acres of wheat must be reserved as the number of times 6 is contained in 36, or 6 acres.

(2) By the second method, the yield of the crop per acre and the quantity of feed that the herd of hogs will consume per day are estimated. Suppose that the yield of wheat is 30 bushels, or 1,800 pounds, per acre and the herd of hogs will consume 400 pounds of wheat per day. If 400 pounds of wheat are consumed in one day, an acre, or 1,800 pounds, will last 4.5 days. If one acre lasts 4.5 days, 8 acres will be required to last 36 days, i. e., from July 10 to August 15.

The quantity of wheat that the herd of hogs will consume per day can be determined quite accurately by weighing their feed for a few days just before they are turned into the field. In the case of growing hogs, they will consume a little more each day as they grow older.

THE AREA OF GRAIN TO HOG OFF AT ONE TIME.

Crops are hogged off in two ways: (1) By subdividing the field with a movable fence into small areas that will last the hogs from 10 to 20 days and (2) by turning the hogs into the entire field in the beginning.

No data are at hand showing which of these methods is more economical. While both are used in the Pacific Northwest, the latter is the one generally practiced. Where crops are used in this way during the late fall and winter in the more humid portions of the wheat belt and west of the Cascade Mountains, where the autumn rains are frequently heavy, the area should probably be limited so that it will be cleaned up in 15 or 20 days. In the arid and semi-arid districts or when used during the dry season in the more humid localities, there is probably no good reason why the area hogged off should not be all that the hogs will clean up nicely during the season. Much larger areas doubtless can be hogged off on sandy or gravelly soils than on clay soils that become sticky when wet.

CROPS SUITABLE FOR PASTURE AND HOGGING OFF.

The three Pacific Northwestern States to which this bulletin is primarily applicable may be divided into three distinct agricultural districts: (1) Western Oregon and western Washington—that portion of these two States lying west of the Cascade Mountains, (2) the wheat belt, and (3) the irrigated valleys. Because of their great variation in topography, elevation, rainfall, soil, temperature, etc., these three districts present a wide range of agricultural possibilities. For this reason the crops that may be used in economical hog production in each area are discussed separately.

CROPS FOR WESTERN OREGON AND WESTERN WASHINGTON.

The moist, mild climate of this district makes it possible to provide an abundance of cheaply grown forage for hogs throughout the entire year. The number of crops which may be used for this purpose is very great. The growing of most of them is discussed in detail in Farmers' Bulletin 271 of this department, "Forage Crop Practises in Western Oregon and Western Washington," to which the reader is referred. Only such points of information as can not be easily found elsewhere are presented here.

USE OF VARIOUS PASTURE CROPS.

Table I shows suitable pasture crops in western Oregon and western Washington, with the dates of planting and use.

TABLE I.—*Pasture crops for western Oregon and western Washington.*

Crops.	When planted.	Approximate dates when used.	Number of hogs an acre will pasture. ¹
Clover.....	A previous year.....	April 1 to November 1.....	8 to 16
Alfalfa.....	do.....	do.....	8 to 16
Rape in rows.....	April 1, 15, and 30.....	June 1 to November 1.....	8 to 14
Rape and oats.....	April 25 to May 15.....	June 25 to November 1.....	6 to 15
Rape and clover.....	May 15 to June 1.....	July 1 to November 1.....	6 to 15
Rape.....	July (in corn at last cultivation). do.....	October 1 to April 1.....	5 to 8
Vetch and wheat, vetch and oats, or vetch alone.	do.....	do.....	5 to 8
Vetch and wheat or vetch and oats.	September (on spring stubble).	November 1 to April 1.....	5 to 8
English rye-grass.....	Early spring or early fall.....	November 1 to July 1.....	5 to 14
Winter wheat.....	September 1 to October 15.....	February, March, and April.....	6 to 12
Vetch.....	September.....	March to July 1.....	8 to 16

¹ The number of hogs that can be pastured per acre depends upon (1) the productiveness of the soil, (2) the variation of the season, (3) the management of the pasture, (4) the size of the hogs, and (5) the kind and quantity of other feed the hogs receive in addition to the pasture.

From a study of Table I it will be seen that pasture may be provided for swine in western Oregon and western Washington throughout the entire year. It is not intended that all of these crops shall be used on any one farm. The purpose of the table is to assist the farmer in the selection of pasture crops which may meet the needs and conditions of his farm.

If intended for late fall, winter, and early spring use, a pasture should not be grazed during the autumn, in order that a large amount of forage may accumulate. This is necessary with almost all winter forage crops, for growth practically ceases when winter begins. The forage that is allowed to accumulate during the autumn is grazed during the winter.

It must be understood also that there are times during the winter when most soils west of the Cascade Mountains become so wet that the tramping of the hogs does a great deal of injury by puddling the soil. For this reason it is generally considered best to remove the hogs from the pasture when a heavy rain falls. This is not always

necessary, however, as, for example, on sandy soils and pastures with a close grass sod.

Clover.—Of the legumes, red clover for well-drained soils and alsike for wet lands are generally the most satisfactory. The clovers make their maximum growth during the months of April, May, and June. When the summer drought comes on, the quantity of forage produced gradually decreases. If a clover pasture is utilized to its fullest capacity during the spring and early summer, it is necessary to provide additional green feed for the dry season. This may be done by grazing the clover meadow during the summer after removing a crop of hay.

Alfalfa.—Alfalfa is not used so generally as clover for hog pasture west of the Cascade Mountains. It has been tried in many localities with varying degrees of success. It has given best satisfaction on the sandy or loamy soils along the watercourses where the water table is at least 4 feet below the surface. Alfalfa is highly successful in the Umpqua and Rogue River Valleys on irrigated and subirrigated land. Under conditions favorable to its growth, it produces an abundance of feed from early spring until late in the fall.

Rape in cultivated rows.—If grown in rows and kept well cultivated, rape furnishes excellent green forage during the dry season when clover pasture is cut short by the summer drought. In growing rape in rows the land is prepared early and kept in good condition until planting time. The best results are secured by making three plantings on approximately April 1, 15, and 30. These three areas are then pastured alternately, the hogs being changed from one to the other. By thorough cultivation rape can be kept growing all summer. It is usually large enough to pasture with light hogs in 6 to 8 weeks after planting. Before brood sows and other grown hogs are turned on the rape, it should be large enough so that they will feed upon the leaves instead of biting off the stem or pulling up the plants. When the fall rains come, rape makes a vigorous growth and can be used until the ground is so wet that the soil is injured by the tramping of the hogs.

Rape and oats.—Summer pasture is also provided by sowing 1 bushel of oats and 4 pounds of rape seed per acre during the latter part of April or early in May. If sown too early in the spring the rains pack the soil so hard that the rape does poorly. Oats and rape pasture is used from the time the growth is 5 or 6 inches high until winter begins. When hogs are pastured on rape and oats they do not work on the latter very much (unless the pasture is grazed closely) until the oats are nearly ripe. In stripping the ripe grain from the straw considerable is dropped on the ground and covered by the tramping of the hogs. The grain that is covered in this way germinates when the fall rains begin. Both the oats and rape then grow vigorously and make excellent fall and winter pasture.

Winter pasture is also provided by sowing rape with oats intended for hay or grain. When sown in this way the rape grows but little until after the oats are harvested and the autumn rains have begun.

Rape and clover.—One of the most satisfactory ways of providing summer pasture is to sow rape and clover together late in May or early in June. For the details of this method, see Farmers' Bulletin 271 of this department.

Rape in corn.—From 3 to 4 pounds of rape seed per acre are sometimes sown in corn during July, just before the last cultivation. If the corn is planted on a well-prepared seed bed and kept thoroughly cultivated, so that the soil will remain moist, the rape usually germinates in about five days. It then furnishes excellent green succulent forage during the autumn while the corn is being hogged off. If the

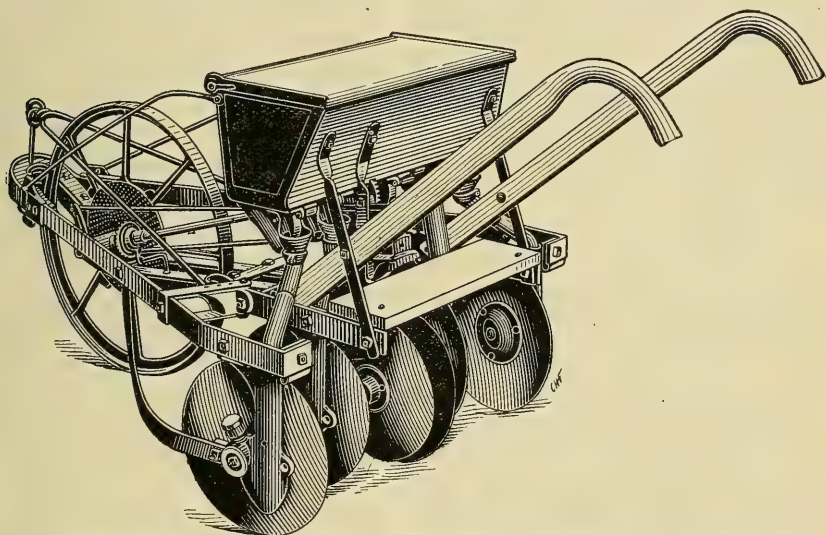


FIG. 5.—A one-horse disk grain drill used for planting grain between the rows of standing corn.

corn crop is husked or cut and removed from the field and the rape allowed to grow until late in the fall, the rape furnishes good pasture from November 1 to April 1.

Vetch and wheat, or vetch and oats, or vetch alone.—Vetch sown alone or with wheat or oats in corn at the last cultivation or in the early fall on spring-plowed stubble land furnishes pasture for hogs during the late fall, winter, and early spring. One bushel of vetch and a bushel of oats or 40 pounds of wheat are used per acre. If sown alone, from 90 to 120 pounds of vetch seed are required per acre. The seed is either planted with a one-horse grain drill which runs between the rows of corn or it is sown broadcast from the back of a horse. A one-horse disk grain drill, which can be used for this purpose, is shown in figure 5. If the latter method is used, a hood is placed over the head of the horse to keep the grain from falling into the animal's

ears. If sown broadcast, the last cultivation of the corn covers the seed.

If vetch and wheat or oats are sown in corn when "laid by" in July, the pasture is ready for use by October 1; if sown on spring-plowed stubble land in the early fall, it is ready about November 1. The pasture may be used during the winter and early spring. If other pasture is not available, these crops will also furnish excellent forage for hogs until late in June. Vetch is also sown alone in the fall and used during April, May, and June.

English rye-grass.—Owing to the excessive winter precipitation west of the Cascade Mountains, the ground is frequently so wet that the tramping of stock is very injurious to most soils. For this reason a grass pasture with a close, tough sod is very desirable for winter use. English rye-grass meets this need admirably. This grass forms a close sod that stands tramping well. It is one of the first grasses to begin growth in the spring and one of the last to cease growing in the fall. A rye-grass pasture may be used from the early autumn until the following July. During the summer drought, growth practically ceases. If kept grazed rather closely, the pasture will last for years.

A permanent English rye-grass pasture may be started by sowing from 10 to 15 pounds of seed per acre with oats or wheat in the early spring or fall. The grain crop is either thrashed or cut for hay. The grass is then ready for grazing the following autumn after being sown. A permanent pasture may be started also by sowing the grass seed with vetch, oats, or wheat on stubble land in the early fall. The mixture of grass, vetch, and grain is used for pasture the following winter and spring. The second year the pasture is a close grass sod that will stand grazing when the ground is wet.

Winter wheat.—Winter wheat sown in the early fall for a grain crop furnishes excellent pasture for hogs during February, March, and April.

GRAIN CROPS TO HOG OFF.

TABLE II.—*Crops to hog off in western Oregon and western Washington.*

Crops.	When planted.	Approximate date when used.
Beardless barley.....	Early spring.....	July 1 to July 20.
Winter wheat.....	September and October.....	July 10 to August 10.
Field peas.....	Early spring.....	July 25 to October 1.
Corn.....	April 20 to May 10.....	September 15 to November 15.

Wheat.—Hogs make rapid and economical gains on wheat until the chaff becomes thoroughly dry. If they are then supplied with green feed, they will do much better. If peas are not available for hogging off during August and September, wheat may be used until the autumn rains begin. Spring wheat may also be grown to take the place of the peas.

Beardless barley.—If no winter wheat is available to hog off, its place may be filled with beardless barley. In fact this crop may take the place of corn and peas as well, being used from the time it is in the stiff-dough stage, about July 10, until winter rains come. Hogs do exceptionally well on it after the rains have softened the kernels.

Peas.—To furnish autumn pasture, one-half peck of wheat or a peck of oats is frequently sown with peas that are to be hogged off. In working upon the mature crop the hogs cause considerable of the oats or wheat to shatter out. Much of this is covered by the tramping of the hogs. When the first fall rains come it germinates and furnishes good pasture.

Corn.—Corn is hogged down to good advantage in much of the territory west of the Cascade Mountains for about six weeks—that is, from the time the kernels are pretty well glazed and dented until late in the fall. After the rainy season is well begun, the hogs get many of the ears down on the wet ground. This causes the corn to mold and spoil. For this reason it is not best to undertake to hog off too late in the season. In the Willamette Valley corn reaches the hogging-off stage about September 15. In the Rogue River Valley it is earlier and in northwestern Washington much later than in the Willamette Valley.

SUCCULENT WINTER FEEDS.

TABLE III.—*Succulent winter feeds for western Oregon and western Washington.*

Crops.	When planted.	When used.
Kale.....	Planted in March or April; transplanted in June.	October 1 to April 1.
Squash.....	May 25.....	November 1 to January 15.
Roots.....	April 1 to May 15.....	November 1 to April 1.
Artichokes.....	Early spring.....	Do.

Thousand-headed kale.—Thousand-headed kale is an excellent succulent winter feed for hogs. The mild winters of western Oregon and western Washington permit kale to stand in the field all winter. It is cut and fed as needed. Unless fed in a rack or on a clean floor, pigs waste a great deal of the kale by tramping it in the mud. Full directions for growing kale will be found in Farmers' Bulletin 271 of this department.

Squashes.—In order to raise squashes successfully the land is manured heavily during the fall or winter, plowed about March 1, allowed to lie for five or six weeks, and then disked, harrowed, and clod mashed until in good condition. From May 1 to 15 it is replowed. Just before the seed is planted, about May 25, the soil is again cultivated.

The squashes are gathered about November 1, stored in a dark place in the barn, and covered with straw to keep them from freezing. They keep better if gathered before the surface of the squashes has been frozen. They are fed from approximately November 1 to January 15.

Root crops.—The mangel-wurzels, half-sugar beet, sugar beet, and white French sugar beet are all used for hog feed. Beets may be stored either in pits or in bins in the barn, or fed from the field. Occasionally there is some loss from freezing if left in the field all winter. Usually, on the other hand, there is much to be gained by feeding from the field, because (1) beets make considerable growth during the late fall and winter, much of which is lost if they are stored; (2) when fed from the field the tops are utilized the same as the roots; and (3) it is much cheaper to feed from the field than to store them first and feed them later. Beets are fed whole.

Artichokes.—Artichokes are planted in rows and cultivated in precisely the same manner that potatoes are grown. The tubers are cut into rather small pieces and planted a little thicker and a little earlier than potatoes.

Artichokes are utilized by turning the hogs into the field in the fall after the tubers have made their growth. If the hogs have been ringed, the ground is loosened up with a plow, enough tubers being plowed out at a time to last a week.

The soil best adapted to the growth of artichokes for hogs is the sandy land along the watercourses. They can be hogged off on such land without seriously injuring the soil during the entire winter. The heavier soils are frequently badly puddled by the tramping of the hogs during wet weather. This can be counteracted by liberally applying coarse fresh manure or straw just before the hogs are turned into the field in the fall. By manuring heavily and working the ground early in the spring, artichokes may be grown on the same land for several years. They are sometimes allowed to volunteer, the land being plowed, worked down, and the crop permitted to come from the tubers left in the soil. This is not good practice, however, it being much more profitable to plant them in rows, so that they can be cultivated. A crop of artichokes that is ready for the hogs is shown in figure 6.

Objection is sometimes made to artichokes on account of the difficulty of getting rid of them when it is desirable to grow some other crop on the land. They may be eradicated by sowing the land to clover, clover and rape, or clover and oats, and pasturing with sheep or cattle during the summer. If no stems and leaves are allowed to grow, no tubers will form. Close pasturing for one season will eliminate artichokes.

CROPS FOR THE WHEAT BELT.

The wheat belt of eastern Oregon, eastern Washington, and northern Idaho presents a great variety of agricultural conditions. The elevation above sea level varies from 1,000 to as much as 3,000 feet. The annual precipitation also varies from approximately 10 inches to 25 inches. In some of the more arid districts where the altitude

is low, the soil is frequently so light that it is subject to blowing and drifting. In the districts where the precipitation is heaviest, on the other hand, the soil is a dark, fertile, silt loam. Owing to these variations crop production varies widely in the wheat belt. For convenience in discussing the cropping and feeding systems which may be used for hogs, the wheat belt is divided into (1) the subhumid or moister districts and (2) the arid and semiarid districts. There is no distinct line of demarcation between them, for they gradually blend into one another.



FIG. 6.—A field of artichokes in the Willamette Valley, Oreg., that is ready for the hogs. When the lower leaves began to die, sheep were turned in. They stripped off the leaves as high as they could reach. Cattle would consume the rest of the leaves.

SUBHUMID OR MOISTER DISTRICTS.

The more humid portions of the wheat belt are generally situated near the mountains. The annual rainfall is usually sufficient to grow alfalfa successfully without irrigation.

USE OF VARIOUS PASTURE CROPS.

TABLE IV.—*Pasture crops for the subhumid districts.*

Crops.	When planted.	Approximate dates when used.	Number of hogs an acre will pasture.
Winter wheat.....	Early in September.....	October 15 to November 15, March 15 to June 1.	5 to 8
Clover.....	April, previous year.....	April 10 to December 1.....	8 to 15
Alfalfa.....	A previous year.....	April 15 to November 15.....	8 to 15
Kale or rape.....	April and May.....	June 15 to December 1.....	8 to 15
Rape and clover.....	May 1.....	July 10 to November 15.....	6 to 14
Winter wheat.....	Early in May.....	June 1 to November 15.....	6 to 15
Wheat in corn.....	July 15 to 20 (at last cultivation of corn).	September 15 to November 15.	6 to 12
Stubble field.....	.....	August 25 to April 1.....	.....

Winter wheat.—Many farmers use the main winter-wheat field for hog pasture. If the autumn rains begin early enough in the fall to do the seeding during the first part of September, wheat usually makes sufficient growth to furnish pasture from October 15 until the ground is so wet that it is injured by the tramping of the hogs. If sown during September, winter wheat also makes very early spring pasture. It is used from the time the ground is settled until the grain begins to head, or until the hogs begin to chew the heads. Ordinarily this will be from March 15 until June 1.

Excellent summer and autumn pasture is provided by sowing winter wheat early in May on a well-prepared seed bed. If not pastured very closely during the autumn, wheat that is sown during May can be used during much of the winter.

If sown just before the last cultivation in corn that has been well cultivated, wheat generally furnishes an abundance of green feed during the autumn when corn is being hogged off.

Clover and alfalfa.—Red clover is adapted to the wheat-growing districts having a claylike subsoil and the maximum precipitation. While alfalfa is adapted to the same territory it has a much wider range of usefulness, for it succeeds with less rainfall and on lighter soils than clover. Clover begins to grow earlier in the spring and continues to grow later in the fall than alfalfa. The young tender growth of clover is not so easily injured by severe frosts as that of alfalfa. Red clover fits nicely into short rotations because it is short lived and so easily killed by plowing. Where the land is to be used continuously for hog pasture for a number of years alfalfa easily stands first.

The carrying capacity of both clover and alfalfa is greatly reduced by the summer drought, and it is usually necessary to provide additional feed during this time.

The essentials in successfully growing both of these crops are given in detail in Popular Bulletin 31 and Bulletin 80 of the Washington Agricultural Experiment Station, Pullman, Wash.

Kale and rape.—Thousand-headed kale and Dwarf Essex rape are very closely related. The mature individual kale plants are generally larger than those of rape. In the more humid portions of the wheat belt of Idaho, Oregon, and Washington few crops are more satisfactory for pasture during the summer and autumn than kale and rape. The green aphid sometimes attacks both of these crops during the last of August. While kale is seldom injured very much, rape is frequently damaged considerably. For this reason kale is the preferable crop. A field of kale is shown in figure 7.

To grow either rape or kale successfully the land to be planted receives an application of stable manure and is plowed during the late fall. As soon as the surface soil is dry enough in the spring,

it is thoroughly cultivated to destroy weeds, germinate weed seeds, and conserve moisture. For early summer use, say the middle of June, the seed is planted as early in the spring as the soil has warmed up well. If the crop is not to be used until July 15, the date of planting may be delayed until about May 1. Seeding at that date gives an opportunity to cultivate the ground several times before the seed is planted. This makes it much easier to keep the crop free from weeds.

While kale and rape may be sown broadcast, the best results are secured by planting in rows about 32 inches apart. Kale is thinned until the plants stand 12 to 14 inches apart in the rows. Rape can be left a little thicker in the row.



FIG. 7.—Thousand-headed kale on the college farm, Pullman, Wash., planted in drill rows 28 inches apart. (Photographed August 23, 1909.)

By pasturing and cultivating two or three times, the crop may be kept green all summer. After the fall rains come both rape and kale make a much better growth than clover or alfalfa. They stand a great deal of severe frost and can generally be used until about December 15. If used only during the late summer and autumn, better results are secured by cutting and feeding kale instead of turning the hogs into the field. When the plants are allowed to become large, the hogs break down and waste many of the leaves.

Rape and clover.—Summer pasture is provided and a stand of clover established at the same time by sowing 3 pounds of rape seed and 8 to 10 pounds of red-clover seed per acre about May 1. The seed is mixed and sown together according to the methods described for sowing clover in Popular Bulletin 31 of the Washington Agricultural Experiment Station. If sown May 1, the rape and clover should be

large enough to pasture by July 1 to 10. Rape makes excellent green forage while wheat, peas, and corn are being hogged off.

Gleaning stubble fields.—Wheat farmers who raise hogs give them the run of the stubble fields from the time the grain is harvested until the land is plowed the following spring. They feed upon the heads that are dropped in harvesting and also on the volunteer grain.

It is frequently supposed that the combined harvester and thrasher will leave so little grain in the field, especially on level ground, that there is nothing to be gained by gleaning the stubble with hogs. It is also supposed that in gleaning a large stubble field hogs will do so much traveling that they make no gains. To show that neither of these assumptions is well founded, the experience of W. H. Steen, Umatilla County, Oreg., in gleaning the stubble field with hogs may be cited.

On August 24, 1910, 90 head of hogs, weighing 6,261 pounds, were turned into 178 acres of wheat stubble. They were in the field without other feed until November 1, when they weighed 8,350 pounds. The gain in live weight per acre was 11.73 pounds. The value of the gain per acre (11.73 pounds) at 6, 7, and 8 cents per pound amounts to 70.4, 82.1, and 93.8 cents, respectively. The stubble land gleaned by the hogs is comparatively level, and a good job had been done in cutting the grain with a combined harvester. On steep land the waste in harvesting is always much greater than on level land, and the gain in gleaning the stubble with hogs should be correspondingly greater.

GRAIN CROPS TO HOG OFF.

TABLE V.—*Crops to hog off in the subhumid district.*

Crops.	When planted.	Approximate dates when used. ¹
Beardless barley.....	Early spring.....	July 5 to August 1.
Winter wheat.....	September and October.....	July 20 to August 20.
Field peas.....	Early spring.....	July 10 to November 1.
Spring wheat.....	do.....	August 1 to September 1.
Corn.....	May 1 to 20.....	September 1 to November 15.
Blue barley or common beardless barley.	Early spring.....	From beginning of autumn rains to midwinter.

¹ Because of the great variation in altitude in the more humid portions of the wheat belt, there is a corresponding variation in the dates at which crops mature. Barley, wheat, and peas, for example, reach the hogging-off stage much earlier when grown at low altitudes than at high altitudes. For this reason the dates in the above table for using the crops are only approximately correct.

A discussion of the use of the crops mentioned in Table V will be found on pages 6 to 9 of this bulletin. The growing of wheat and barley is familiar to all and needs no further comment. The growing of field peas and corn are discussed in Popular Bulletins Nos. 36 and 38, and Bulletin 99 of the Washington Agricultural Experiment Station. These bulletins may be had by applying to the Director of the Agricultural Experiment Station, Pullman, Wash.

WINTER FEEDS.

TABLE VI.—*Winter feeds for the subhumid districts.*

Crops.	When planted.	Approximate dates when used.
Alfalfa hay.....	A previous year.....	November 1 to April 15.
Roots.....	April and May.....	Do.
Artichokes.....	April.....	October 15 to May 1.
Bundle or headed wheat.....	Fall or spring.....	Late fall, winter, and early spring.
Field peas (unthrashed).....	Early spring.....	Do.
Bundle or headed barley.....	Fall or early spring.....	Do.

Alfalfa hay.—Alfalfa hay is probably the most satisfactory winter roughage that may be provided for hogs in the subhumid wheat districts. If intended for hogs, it is cut green a little before the appearance of the first blossoms. It is also best to take it from a portion of the field where the stand is thick. The hay will then be fine, palatable and rich in protein.

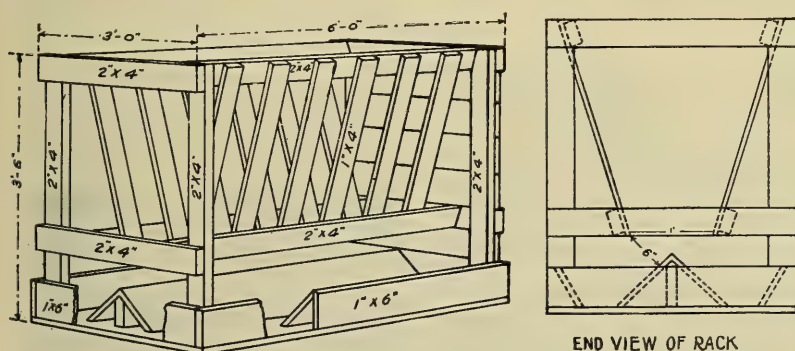


FIG. 8.—Rack for feeding hay to hogs.

Alfalfa hay is usually fed in one of two ways, whole or cut. Whole hay is generally fed in racks. Figures 8 and 9 show racks used for feeding hay to hogs. Hay is also fed on the surface of the ground. By either of these methods there is considerable waste, especially if the hay is coarse. One of the most popular and satisfactory ways of feeding alfalfa hay to hogs is to run it through a hay cutter, chopping it into lengths of about one-half inch. The hay is then mixed with chopped or rolled wheat or barley. The mixture is moistened with all of the water that it will absorb, and allowed to stand for 12 hours before it is fed. Some soak the hay and add the grain just before feeding. During very cold weather the hay may be wet with hot water and fed immediately. Where it is not necessary to hasten the growth of the hogs alfalfa hay may form one-half of the ration by weight. Where a rapid gain is desired a ration consisting of one-fourth alfalfa hay and three-fourths grain is more satisfactory.

Root crops.—The sugar beet, the white French sugar beet, man-gels, carrots, and rutabagas are all used for fall and winter hog feed.

The success of root crops largely depends upon the preparation of the seed bed. In growing sugar beets in the vicinity of Waverly, Wash., the following has been found a very satisfactory way of preparing land for this crop. Stubble land is disked or plowed shallow in the autumn. As soon as in condition to work in the early spring it is plowed 7 or 8 inches deep and then harrowed, planked, and rolled again and again until a firm, mellow seed bed is formed. The time of planting depends on the season. In localities whose altitude is from 2,000 to 2,500 feet, root crops are usually planted the last of April or early in May. For winter use roots are stored either in cellars or pits. Roots are generally fed in connection with a grain ration. The hogs usually receive all of the roots that they will clean up and sufficient grain to make them thrive and grow as desired.



FIG. 9.—An easily and cheaply constructed rack for feeding hay to hogs. The sides consist of ordinary hog-fencing wire stapled on a frame.

Artichokes.—On rich, mellow land that retains moisture well artichokes usually yield better than potatoes. But on land that dries out quickly the yield is not very satisfactory. The methods given on page 16 of this bulletin for growing artichokes will apply in the main for this district also.

The hogs are turned in late in the fall, about the time that alfalfa or clover pasture is failing. Some allow the hogs to work on the tubers at will from the last of October until May 1. Others prefer to use artichokes only in the late fall and early spring, the hogs being removed from the field during the winter, when the ground is so wet that their rooting will puddle the soil. The hogs are returned to the field as soon as the ground has settled in the early spring. Used in this way artichokes fill in two periods, the late fall and early spring, when green feed is scarce. As with the root crops, hogs must also receive a grain ration of some kind when feeding upon artichokes if

rapid gains are desired. When the ground is frozen hard other feed must be provided.

Unthrashed wheat.—Many hog raisers use headed or bundle wheat to carry dry brood sows and young shoters through the winter. When feeding upon the unthrashed grain the hogs get considerable roughage in chewing the heads. They are also compelled to eat more slowly and to masticate their food better than when feeding upon thrashed grain. When the grain is fed in the straw the thrashing bill is saved and the hogs are kept busy during much of the time. Unthrashed wheat and artichokes or roots of some kind make a good combination for wintering hogs.

Field peas.—In some localities field peas are stacked and the unthrashed vines fed to hogs during the late fall, winter, and early spring. Mature pea grain is a concentrated feed, very rich in protein. For this reason hogs should receive other feed in addition to the peas to dilute the ration. Any of the root crops, artichokes, or potatoes are excellent for this purpose.

Unthrashed barley.—In using unthrashed bearded barley for winter feed for hogs, a large quantity is thrown into the feed lot at a time in order that the beards and kernels may become wet and soften. If fed dry, the kernels are too hard to be eaten readily.

ARID AND SEMIARID DISTRICTS.

The arid and semiarid districts may arbitrarily be designated as that portion of the wheat belt whose normal precipitation is insufficient to grow alfalfa successfully. In much of this region, however, alfalfa can be grown profitably for hog pasture by keeping the stand very thin and cultivating it thoroughly in the late fall and early spring. If sown rather thinly in rows about 24 to 36 inches apart and cultivated occasionally during the spring and summer, alfalfa will make profitable hog pasture over a very wide territory now considered too dry for that crop. The crops mentioned in Table VII will provide pasture during much of the year in the dry region.

PASTURE CROPS.

TABLE VII.—*Pasture crops for the arid and semiarid districts.*

Crops.	When planted.	Approximate date when used.	Number of hogs an acre will pasture.
Winter wheat.....	October.....	April 1 to May 15.....	6 to 10
Beardless barley.....	February or March.....	May 1 to June 15.....	5 to 10
Spring wheat.....	March.....	May 1 to July 1.....	5 to 10
Winter wheat or beardless barley.....	May.....	June 15 to August 1-25.....	5 to 8
Field corn and Early Amber sorghum.....	April 10 to May 10.....	July until autumn frosts.....	4 to 7
Stubble field.....	.....	August 25 to April 15.....	.....

Wheat.—Wheat is used for hog pasture as follows:

(1) As soon as the surface of the ground is dry in the spring, about April 1, the hogs are turned into the main crop of winter wheat that is grown for market. Some prefer to use the winter wheat until it begins to joint; that is, for about a month or six weeks. Others use it until the hogs begin to chew the heads of wheat, and still others harvest with the hogs in the field.

(2) Spring wheat sown the last of February or early in March is generally large enough for pasture, 3 to 4 inches high, by May 1. By pasturing it rather closely it will stay green until about July 1.

(3) Summer pasture is provided by sowing either spring or winter wheat about May 1. Land that is sown at this date is plowed during the late fall, in the winter, or very early in the spring. To destroy weeds and retain moisture it is kept thoroughly cultivated from early spring until the wheat is sown. The pasture is ready for use in about six weeks from date of planting. If grazed closely, it should remain green until in August.

Barley.—The common beardless barley is also sown in the early spring and early in May for spring and summer pasture. Barley comes more quickly and makes more feed than wheat. The hogs also like it better than wheat up to the time it has headed out.

Corn and sorghum.—Field corn and several varieties of sorghum are grown in a limited way in the dry portion of the wheat belt for hog pasture. The principal varieties of sorghum are kafir, Jertusalem corn, milo, and Amber sorghum. Just which of these is most satisfactory when grown as a grazing crop or to cut and feed green has not been fully determined. On account of the succulency and high sugar content of its stems as well as its habit of suckering after being cut or eaten down, Amber sorghum is probably the best of the varieties named above. The variety grown is locally known as Early Amber sorghum. Field observations seem to indicate that Amber sorghum is best adapted to the extremely dry districts where the altitude is rather low, and corn to the higher districts. These crops need to be further tested in limited areas to determine which are most profitable.

Corn and sorghum are grown in much the same way. To be successful, the preparation of the seed bed must receive special attention. Perhaps the most satisfactory way to prepare the land for these crops is to plow during the late fall or winter and then cultivate thoroughly from early spring until planting time. Sorghum is planted a trifle later than corn, in rows 3 to 3½ feet apart with a grain drill. The seed is dropped 10 to 15 inches apart in the row. To firm the soil and cause the seed to germinate quickly, a corrugated roller or subsurface packer is run just behind the drill. The cultivation is the same as that of corn. The crop is either cut and fed green or the hogs are turned into the field when the sorghum or corn is 14 to 18 inches high. The former method gives by far the most feed.

Corn and sorghum are generally used in a 2-year rotation with wheat or barley, the land being in sorghum or corn for summer green feed one year and in barley or wheat to pasture or hog off the next.

Gleaning stubble fields.—If the farm is fenced hog tight, the hogs have the run of the stubble field from the time the grain is harvested until the land is plowed the following spring. The volunteer grain makes the earliest green feed in the spring.

GRAIN CROPS TO HOG OFF.

TABLE VIII.—*Crops to hog off in the arid and semiarid districts.*

Crops.	When planted.	Approximate dates when used. ¹
Beardless barley.....	Early spring.....	June 20 until autumn rains begin.
Winter wheat.....	October.....	July 1 to opening of stubble field or until autumn rains begin.
Spring wheat.....	Early spring, February and March.....	July 15 to opening of stubble field or until autumn rains begin.
Field peas.....	do.....	July 20 until autumn rains begin.
Blue barley or the common beardless barley.	do.....	From beginning of autumn rains to late winter—October 15 to February 10.

¹ The altitude of the arid and semiarid districts varies from 1,000 to 3,000 feet. For this reason the dates at which the crops in the above table mature will vary considerably. The dates given for the use of these crops, therefore, are only approximations.

Whether or not wheat and peas shall be used from the time they are available in the early summer until the autumn rains have softened the barley sufficiently to be hogged down will depend upon the number of hogs kept on the farm. Where only enough hogs are kept to glean the stubble field, peas and wheat are used only until the grain is thrashed and the stubble field is open. Where more than enough hogs are kept to clean up the stubble field, wheat and peas can be profitably hogged off until the barley is in condition to use.

Somewhat limited observations indicate that field peas in the dry parts of the wheat belt seldom have nodules on their roots. The yield also is usually light. The lack of nodules, the light yields, and the high price of seed make the production of peas questionable. It is probable that they may be grown profitably in rows as a cultivated crop. At the experimental farm at Moro, Oreg., peas are planted in double rows 7 inches apart with 35-inch spaces between the double rows. The peas are planted in this way with a grain drill by stopping up a part of the feed cups. The peas support each other and stand up better when planted in this way. They are cultivated with a spike-tooth harrow until about 4 or 5 inches high. They then receive shallow cultivation between the rows until the vines lop over.

WINTER FEEDS.

The feeds that may be used economically to carry hogs through the winter are standing barley and headed wheat. Field peas may also be stacked and fed without thrashing.

CROPS FOR THE IRRIGATED VALLEYS.

Much of the irrigated land along the Columbia River, on the one extreme, is less than 400 feet above the level of the sea. Some of the irrigated mountain valleys, on the other hand, have an elevation of

3,500 to 4,000 feet. At the low altitudes pasture is available much earlier in the spring and later in the autumn than at the higher altitudes. In the mountain valleys all of the grain fed is raised, while in the lower districts most of the grain consumed is purchased from the near-by wheat farms. In the lower districts corn is successfully grown. In the higher valleys corn has not proved a success.

PASTURE CROPS.

TABLE IX.—*Pasture crops in the irrigated valleys.*

Crops.	When planted.	Approximate dates when used.	Number of hogs an acre will carry.
Red clover.....	Previous year.....	March 25 to November 10.....	10 to 20
Do.....	Early spring with wheat, oats, or barley.	After grain is harvested to November 10.	10 to 20
Alfalfa.....	Previous year.....	April 1 to to November 1.....	10 to 20

Alfalfa is most generally used for hog pasture under irrigation. There are many who prefer clover, however, especially in the mountain valleys, because it starts growth earlier in spring and is less injured by fall frost than alfalfa. The two crops are sometimes grown together. It is claimed that a mixture of the two will carry nearly one-third more hogs per acre than either grown alone.

In the mountain valleys where the cereals are important crops, clover fits into the rotations better than alfalfa. In the Powder River Valley, Oreg., red clover is grown in a 2-year rotation with wheat, oats, or barley. The clover is sown in the early spring and after the grain is harvested makes excellent pasture until winter. The following June a crop of hay is cut. About the middle of July, when the second crop is about 10 inches high, the clover is plowed under and the ground worked down immediately. The following spring the land is again sown to clover and wheat, oats, or barley. Where there is plenty of water for irrigation throughout the season, the clover sod is not plowed under until during the autumn.

WINTER FEEDS.

TABLE X.—*Winter feeds in the irrigated valleys.*

Crops.	When planted.	When used.
Alfalfa hay.....	A previous year.....	November 1 to April 15.
Root crops.....	April and May.....	Do.
Bundle or headed wheat.....	Fall or spring.....	Late fall, winter, and early spring.
Field peas.....	Early spring.....	Do.
Artichokes ¹	April (same as potatoes).....	November 1 to April 15.

¹ Artichokes are best adapted to the lower irrigated districts, where the winters are open enough to permit the hogs to work on the tubers. They are used from the time that alfalfa pasture fails in the autumn until it is available again in the spring. Even in the lower valleys there are times during the winter when the ground is frozen too hard for the hogs to root out the tubers. Alfalfa hay, roots, or other feed must then take the place of the artichokes.

A discussion of the use of these crops will be found under "Winter feeds," pages 21 to 23.

CROPS TO HOG OFF.

TABLE XI.—*Crops to hog off in the irrigated valleys.*

Crops.	When planted.	Approximate dates when used. ¹
Beardless barley.....	Early spring, April.....	August 1 to November 15.
Club wheat.....	September or October.....	August 5 to September 15.
Field peas.....	Early spring, April.....	August 20 to November 15.
Club wheat.....	do.....	August 20 to October 1.

¹ The dates for using the crops in the table above are applicable to localities whose altitudes range from 3,000 to 4,500 feet. At lower altitudes these crops are ready for use much earlier.

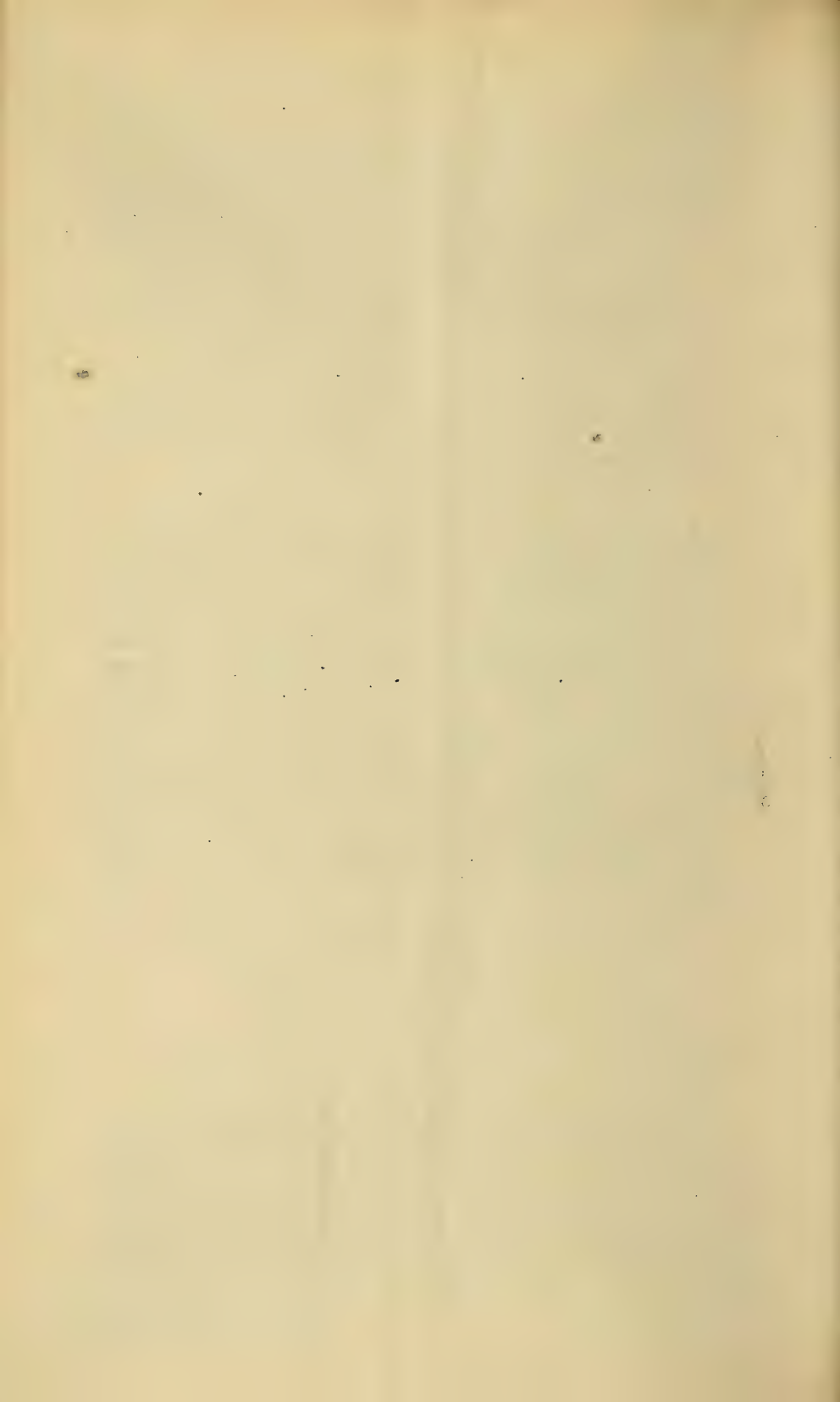
The hogging off of crops under irrigated and nonirrigated conditions is so similar that the discussion of the use of these crops on pages 5 to 10 and 14 and 15 of this bulletin will be found applicable in the irrigated districts.

SUMMARY.

During recent years the hog industry in the Pacific Northwest has been inadequate to supply the local demands for pork and pork products. This has caused the average price of pork to be relatively high and has made it necessary to ship a large percentage of the hogs slaughtered and bacon consumed from east of the Rocky Mountains.

It is possible to provide pasture for hogs in most of this region throughout much of the year. In most localities it is also possible to provide crops that may be hogged off during several months of the busy season. The crops generally used for this purpose are wheat, field peas, corn, and barley. By supplementing well-managed pasture with the proper grain rations and utilizing the ability of the hog to harvest grain crops for himself, the average cost of producing pork may be materially reduced. These conditions offer an opportunity for profitable pork production in the Pacific Northwest on a much larger scale than at present practiced.







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No. 69



Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief,
and the Bureau of Animal Industry, A. D. Melvin, Chief.

March 28, 1914.

(PROFESSIONAL PAPER.)

CICUTA, OR WATER HEMLOCK.

By C. DWIGHT MARSH and A. B. CLAWSON, *Physiologists, Drug-Plant and Poisonous-Plant Investigations, Bureau of Plant Industry*, and HADLEIGH MARSH, *Veterinary Inspector, Bureau of Animal Industry*.

INTRODUCTION.

HISTORICAL SUMMARY.

Among poisonous plants the genus *Cicuta* is of especial interest, as it is probably the most violently toxic of all the plants growing in temperate regions. Since the middle of the sixteenth century the genus has been definitely known, and the symptoms produced by it have been accurately described many times. Before that time, if recognized at all, it was not distinguished from *Conium*. The term *Cicuta* occurs frequently in Latin literature, but without any doubt was used as the equivalent of the Greek *Κωνεϊον*. Whether the hemlock used by the Greeks and Romans for the punishment of criminals and for suicidal purposes was an extract from a single plant or a compound extract of several plants, as thought by some, may never be known, but in any case it is evident that plants of the genus *Cicuta* as recognized to-day were not used. The symptoms produced by the hemlock are described in detail by Plato in connection with the death of Socrates and are very different from those produced by *Cicuta*. There seems to be little doubt that *Conium* was the principal constituent of the hemlock and perhaps the only substance used.

Albert Regel, 1876-77,¹ has gone into great detail in discussing the history of the "hemlock" and "water hemlock," with copious quotations from ancient authors. Inasmuch as *Cicuta* is not found in any abundance in Greece and Italy, it may, perhaps, fairly be questioned whether the Greeks and Romans had any knowledge of the

¹ For complete titles of works cited in this bulletin, see list on pages 24 to 27.

NOTE.—This bulletin describes water hemlock and its toxic effect upon animal life when taken into the system; it points out the distinction between it and other umbelliferous plants, particularly *conium*, with which it is most likely to be confounded. As the toxic principle is largely confined to the rootstock, the tops and seeds if they become mixed with hay are not a source of danger. The subject is of general interest, as *cicuta* is found in nearly all parts of the United States.

plant. To Konrad Gesner is generally given the credit of first clearly distinguishing *Cicuta* from *Conium*. In 1541, in his *Historia Plantarum*, he speaks of it as *Sium*, but later he calls it *Cicuta aquatica*. In his edition of Dioscorides, 1543, he says "Recentiores faciunt duo genera, aquaticae frigentis naturae, terrestres calide: verum quonam nullum idoneum praeferunt autorem, vereor ne, ut feresolent, hallucinentur." By the first he probably means *Cicuta*, and by the second, *Conium*. In 1561, in "Horti Germaniae," f. 253, he says "*Cicuta aquatica*, herba venenosa, Bartzkenkraut Saxonibus, G. Circa paludes & in paludum marginibus sponte oritur, ut ad lacum Felium agri Tigurini plantare si quis velit, in aqua aut loco palustri pangatur oportet."

In 1679 was published "*Cicutae Aquaticae Historia et Noxae*," by J. J. Wepfer. This book of 336 pages is a rather elaborate work, based on a case of poisoning in which two boys and six girls were involved. In the first nine chapters, comprising about one-half the book, the plant is described and a detailed account of the cases of poisoning given; there is a discussion of the symptoms, of the physiology and pharmacology of the cases, and details of the autopsies are given. In the tenth chapter is an account of some experimental work. In the chapters from the eleventh to the twenty-first, inclusive, other poisons are taken up and discussed. The twenty-second chapter is concerned with the uses of *Cicuta*, and the twenty-third and last with remedial measures in cases of poisoning. While written in a diffuse style, with much extraneous matter and containing many errors, it is on the whole a very remarkable work. When treating of facts Wepfer's statements are clear-cut and accurate. His description of the symptoms of the poisoned children is not only one of the best accounts of the symptoms of *Cicuta* poisoning ever written, but is handled in a graphic style that could hardly be excelled. (See pp. 17-18.)

In 1687 Wepfer published a short paper giving details in regard to four cases of poisoning, one of them being fatal. While Gesner was the first to distinguish what is now known as *Cicuta* in his *Cicuta aquatica*, Wepfer was the first to set forth clearly the peculiar poisonous properties of *Cicuta*.

Wepfer attempts to give the synonymy of preceding authors; for example, he gives—

Oenanthe cicutae facie succo viroso crocante Lobel, 1570, p. 326.

Cicutaria palustris tenuifolia Bauhin, 1623. Lib. IV, Sec. V, p. 161.

Cicuta aquatica Gesneri Bauhin, 1651. Lib. XXVII, p. 175.

In regard to these and other identifications, it may be said that the plant descriptions of that time were not complete enough to make identification certain from morphological characters. The habits of these two genera, *Conium* and *Cicuta*, however, sometimes show pretty clearly which is meant. *Conium* grows in fairly dry ground

in the neighborhood of towns, while *Cicuta* grows in wet places. So when Ray speaks of *Cicutaria palustris*, 1704, Lib. VIII, p. 257, we can be reasonably certain that he means *Cicuta*. If the symptoms of poisoning are given, as in Wepfer's work, the identity of the plant is without question.

During the seventeenth century *Cicuta* was mentioned by other authors, but little was written of it as a poisonous plant.

In 1723 Helds, Weinmann, and Goritz described a case of three students near Regensburg who ate the root of *Cicuta virosa* with resulting illness and two fatalities. There are three independent accounts, one by each of the writers mentioned, and the symptoms and autopsy findings are described in some detail. Weinmann tells of the death of seven persons near Nuremberg. Goritz grew the plant and gives a description of it.

The next account of importance was by Schwencke in 1756. The original paper was in Dutch, but a German translation by Müller was published in 1776. After a description of the plant he gives the details of the poisoning of four children near the village of Overschie. They were left to themselves in their home, and the mother on her return found them scattered about the floor "struggling with death." Three of the four died. Autopsies were made on two, and Schwencke gives the details of the autopsies and discusses the symptoms fully.

Up to the nineteenth century there were many other references to *Cicuta*, some of which gave some little information in regard to its poisonous properties, but the foregoing account includes the more important papers. All of these accounts were concerned with the European species, *Cicuta virosa*.

During the nineteenth century a large number of cases of poisoning by *Cicuta virosa* were reported, the greater number being in Germany. These reports bear a close resemblance to each other. Most of the cases were of children, and the descriptions of symptoms differ but little, except that in some cases greater detail is given. Much of this literature will be referred to in the further discussion of the subject.

Apparently the first mention of *Cicuta* as a poisonous plant in America was by Schwencke, who speaks of it as the Virginian "Wasser Schierling." Schoepf, in his *Materia Medica Americana*, 1787, makes the following statement: "Ob affinitatem genericam cum *Cicuta virosa* partim, suspecta esse deberet; id quod testimonium Schwenkii, de *Cicuta aquatica*, p. 28, confirmat, qui hanc plantam Cephalalgiam et vertiginem causare dicit."

In this connection it should perhaps be noted that the so-called *Cicuta venenosa* described in connection with a case of poisoning by Greenway, 1793, was not *Cicuta*. In the Kew index this name is

given as a synonym of *Angelica hirsuta*, *A. villosa*. The symptoms described do not at all correspond to those produced by *Cicuta*.

Stockbridge, 1814, tells of the poisoning of three boys, with one fatality, giving details of the symptoms and treatment. He tells also of another case of a boy 6 or 7 years old who died after violent convulsive fits "and the most awful and exquisite sufferings I ever witnessed."

Ely and Muhlenberg, 1815, tell of a similar case of three boys, two of whom died. Bigelow, 1817, describes the plant, giving a general statement in regard to its poisonous properties, and refers to the cases mentioned by Stockbridge and Ely.

Hazeltine, 1818, tells of the "fatal effects of a poisonous root." He did not identify the plant, but his account of the symptoms makes it certain that it was *Cicuta maculata*.

During the nineteenth century a considerable literature in regard to poisoning by *Cicuta* in North America grew up, a large part of it relating to losses of live stock, although there have been very many recorded cases of the poisoning of human beings, and it is known that many cases, perhaps the larger number, have not been published. Most of these accounts are more or less fragmentary in character, and it is not considered necessary to give a synopsis of them.

THE GENUS *CICUTA*.

The following description of the genus *Cicuta* is compiled from the last edition of Gray's Manual:¹

A perennial umbellifer growing from a rootstock, with pinnately compound leaves and serrate leaflets. Involucre usually none, involucels of several slender bractlets, flowers white. Fruit ovoid to nearly orbicular, glabrous, with strong, flattish, corky ribs, the lateral largest; oil tubes conspicuous, solitary; stylopodium depressed; seed nearly terete.

The genus is distributed in the northern continents. A large number of species have been described, most of which are so closely related to each other that in many cases the validity of the species has been questioned. The common species of the eastern United States is *maculata*, which has been, by some, considered as not specifically distinct from the European *virosa*.

Probably all species are equally poisonous, and in popular parlance no distinction of species is made.

DISTINCTION BETWEEN *CICUTA* AND *CONIUM*.

From the standpoint of a poisonous plant *Cicuta* is more likely to be confounded with *Conium* than with any other umbelliferous plant.

¹ Seventh edition, p. 614.

For comparison with the diagnosis of *Cicuta* there follows a diagnosis of *Conium* compiled from Gray's Manual:¹

A biennial umbellifer with spotted stems, large decomposed leaves with lanceolate pinnatifid leaflets. Involucre and involuclers of narrow bracts, flowers white. Fruit ovate, flattened at the sides, glabrous, with prominent wavy ribs; oil tubes none, but a layer of secreting cells next the seed, the face of which is deeply and narrowly concave.

Leaves and flowers of water hemlock (*Cicuta vagans*) are shown in Plate I, while a young plant of the same species is illustrated in Plate II. For comparison, a branch of *Conium maculatum* is shown in Plate III.

It will be seen that *Cicuta* and *Conium* are clearly distinguished morphologically by the leaves and fruit and by the presence of an involucre in *Conium* and its absence in *Cicuta*. These characteristics, however, are hardly sufficient to enable one unskilled in botany to make the distinction readily.

A peculiarity of the rootstock which is not mentioned by the systematic botanists makes it comparatively easy to distinguish *Cicuta* from any other umbellifer that is likely to be found in the same locality. If the rootstock is cut longitudinally there will be seen, more or less clearly, a number of transverse chambers, as shown in Plate II.

These chambers are not as distinct in the spring as later in the season, but they can always be recognized. This peculiarity of the root was noted in *Flora Danica* in 1765, a figure showing the chambers. They were mentioned by Trumel, 1838, and Maly, 1844, and have been figured by a number of more recent authors. It should be noted, too, that while *Conium* grows in fields and waste places, *Cicuta* grows in wet places, like swamps and along irrigating ditches, the old specific name *aquatica* being a particularly appropriate one.

POPULAR NAMES.

Among English-speaking people the *Cicuta* is most commonly known as "water hemlock" or "cowbane." Other names are "parsnip" (or "wild parsnip"), "snakeroot," "spotted hemlock," "spotted parsley," "snakeweed," "beaver poison," "musquash root," and "muskrat weed."

In New Mexico it has been known as "pecos." According to Muhlenberg, an Indian name was "utcum."

Among the Germans it is known as "Wasserschierling," sometimes as "giftiger Schierling." "Schierling" seems to be more commonly applied to *Conium*, although apparently this distinction between "Wasserschierling" and "Schierling" is not always made. It is also known as "Wüterich," "giftiger Wüterich," "Parzenkraut," "Tollkraut," and "Tollrube."

¹ Seventh edition, p. 613.

By the French it is known as "Ciguë vireuse," "Ciguë tachetée" being applied to Conium.

SPECIES OF CICUTA REPORTED AS POISONOUS.

The following species of *Cicuta* have been reported as poisonous: *C. maculata*, *bulbifera*, *vagans*, *bolanderi*, *occidentalis*, *californica*, *curtisii*, *douglasii*, *purpurea*, *tenuifolia*, and *virosa*. In some cases this belief is supported by strong experimental evidence. This evidence is especially strong in regard to *maculata*, *vagans*, *occidentalis*, *californica*, and *virosa*. There is every reason to believe that all species of *Cicuta* are poisonous, and possibly all equally so.

LOCALITIES WHERE CICUTA POISONING HAS OCCURRED.

The number of reported cases of poisoning by *Cicuta* in Europe is very large, by far the greater number having occurred in Germany.

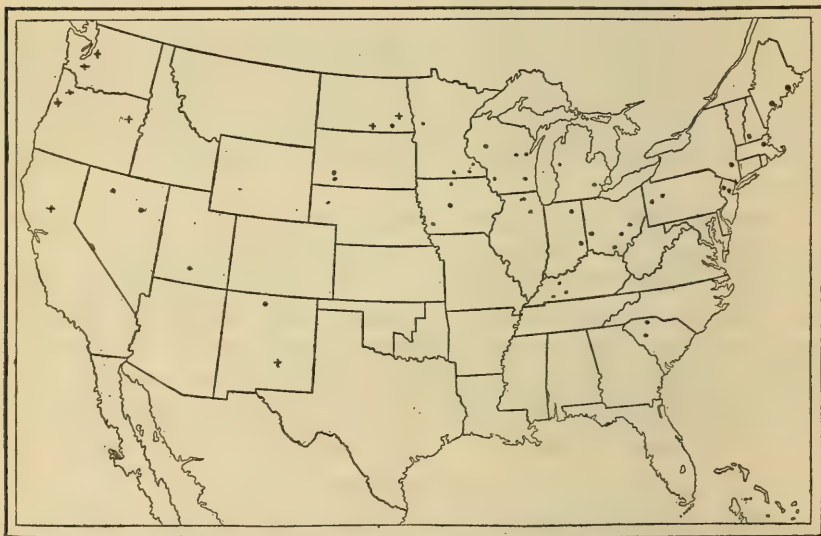


FIG. 1.—Map of the United States, showing the distribution of recorded cases of poisoning by *Cicuta*. Dots indicate the locations of poisoning of human beings, while crosses show the locations of cattle poisoning.

In figure 1 the recorded cases of poisoning in the United States have been plotted, dots indicating the places where members of the human family have been poisoned, while crosses show the localities of cattle poisoning. This chart has been compiled from publications and from definite records in the Office of Poisonous Plants of the United States Department of Agriculture. The first published account was by Stockbridge, 1814. Figure 1 by no means represents the entire number of cases. The compilation of this chart brought out in a surprising manner how imperfectly such cases have been put on

record. For example, there seems to be no definite record of poisoning in Montana. Yet in the year 1900 alone, according to Chesnut and Wilcox, there were five cases of poisoning of human beings in the State, resulting in four fatalities, and a loss of 30 head of cattle and 80 sheep. These could not be plotted, as no definite localities were given. The writers of this bulletin have been informed of many losses of cattle in Colorado, but no accounts were sufficiently definite to admit of plotting.

In regard to sheep, we have a definite local record of only one case of poisoning, at Klamath Falls, Oreg. Yet the yearly losses are heavy. Figure 1, then, must not be considered as giving more than a very incomplete record.

The greater number of cases recorded in the East as compared with the West is partly due to the greater density of population and partly to the special interest taken in the subject in some localities. The number of locations in Wisconsin is largely due to the interest which Prof. Power took in verifying reported cases in that State.

LOSSES OF LIVE STOCK FROM CICUTA POISONING IN THE UNITED STATES.

There are no data from which we can make a reliable estimate of the stock losses from *Cicuta* poisoning. One man in Oregon, presumably estimating the loss in his immediate neighborhood, makes it 10 per cent. Slade, 1903, estimates a loss of a hundred head of cattle a year in Oregon.

Chesnut and Wilcox, 1901, say that in 1900 in Montana 30 head of cattle and 80 head of sheep were lost. Probably the losses in the aggregate are very small. Individual owners of stock have occasionally lost rather heavily, but the total loss does not compare at all with the deaths from other poisonous plants, such plants, for example, as the locos and larkspurs.

USES OF CICUTA.

Most plant substances with positive, evident characteristics have been assumed to have properties useful in medicine. As would be supposed, *Cicuta*, with its violent toxic character, has attracted attention and has been used for a great variety of diseases. Wepfer, 1679, Chapter XXII, discusses its uses in some detail, but most, if not all, that he says refers to *Conium* rather than *Cicuta*.

Gadd, 1774, says that the Finns drive crickets from their homes with *Cicuta*. It may be questioned, however, whether this is anything more than a story that he had heard.

In later times *Cicuta* has been used in medicine to a limited extent. Rafinesque, 1828, p. 110, says:

A few grains have been given in schirrose and scrofulous tumors and ulcers, with equal advantage, but a larger dose produces nausea and vomiting; the doses should be very small, often repeated, and gradually increased. It has been used as a gargle for sore throat, but safer substances ought to be preferred.

In Siberia the crushed nut is used for syphilitic symptoms, and in Norway for gout, while the seeds have been used as a diuretic.¹

In the nineteenth edition of Wood and Bache's Dispensatory of the United States, p. 1449, are the following statements: "At present the plant (*Cicuta virosa*) is never used internally, and rarely externally as an anodyne poultice in local pains."

"*Cicuta (maculata)* has been highly lauded as a specific in nervous and sick headache, but is rarely, if ever, used." (Stearns, 1858, p. 253.)

Dragendorff, 1898, p. 487, states that in Oregon *Cicuta* is used as an arrow poison.

Cicuta has sometimes been used for committing suicide, although it is probable that the statement which is made by some writers to the effect that it was kept by the people of Marseilles for this purpose is inaccurate, as it is more likely that Conium was used.

Rafinesque, 1828, page 110, says "The Indians when tired of life are said to poison themselves with the roots of this plant."

Caillard, 1829, tells of a laborer who purchased and ate the root for suicidal purposes, but recovered after being given an emetic.

Trojanowsky, 1874, relates how a laborer, after a drunken spree and a domestic quarrel, left home and was the next day found dead, the cause of death being *Cicuta*. The evidence was considered sufficient to prove that he ate the root of *Cicuta virosa* with the deliberate purpose of committing suicide.

Trojanowsky refers also to another case, the "Kobeilla'sche Process," but it has been impossible to verify this, as the reference in Trojanowsky's paper is evidently wrong.

Přibram, 1900, tells of an interesting case. A woman having suffered considerable domestic infelicity, on her way to arrange for a divorce called on a fortune teller to find out whether she would succeed in the separation. The fortune teller told her that the separation was unnecessary, as her husband would not live more than one year and advised her to measure the shadow of her husband with a stick, throw the stick upon a stream, saying "I lay down not this stick but thy life, and as the stick becomes broken in its passage, so shall thy life be cut off." Upon the woman replying that she did not wish her husband to die, the fortune teller went to a swamp and gathered three roots, calling them "neapte de boalta," and told her to make a mash of two of these roots, two potatoes, some corn meal, sheep cheese, and onions, and bake a cake of it for her husband to eat. After eating this root, her husband would go about for three months in a stunned condition and would not abuse her or compel her to live with him. If her husband after eating the cake should become ill, the fortune teller would give her tea, so that he should not die.

¹ Brandt, Phoebus, and Ratzeburg, 1838, p. 111.



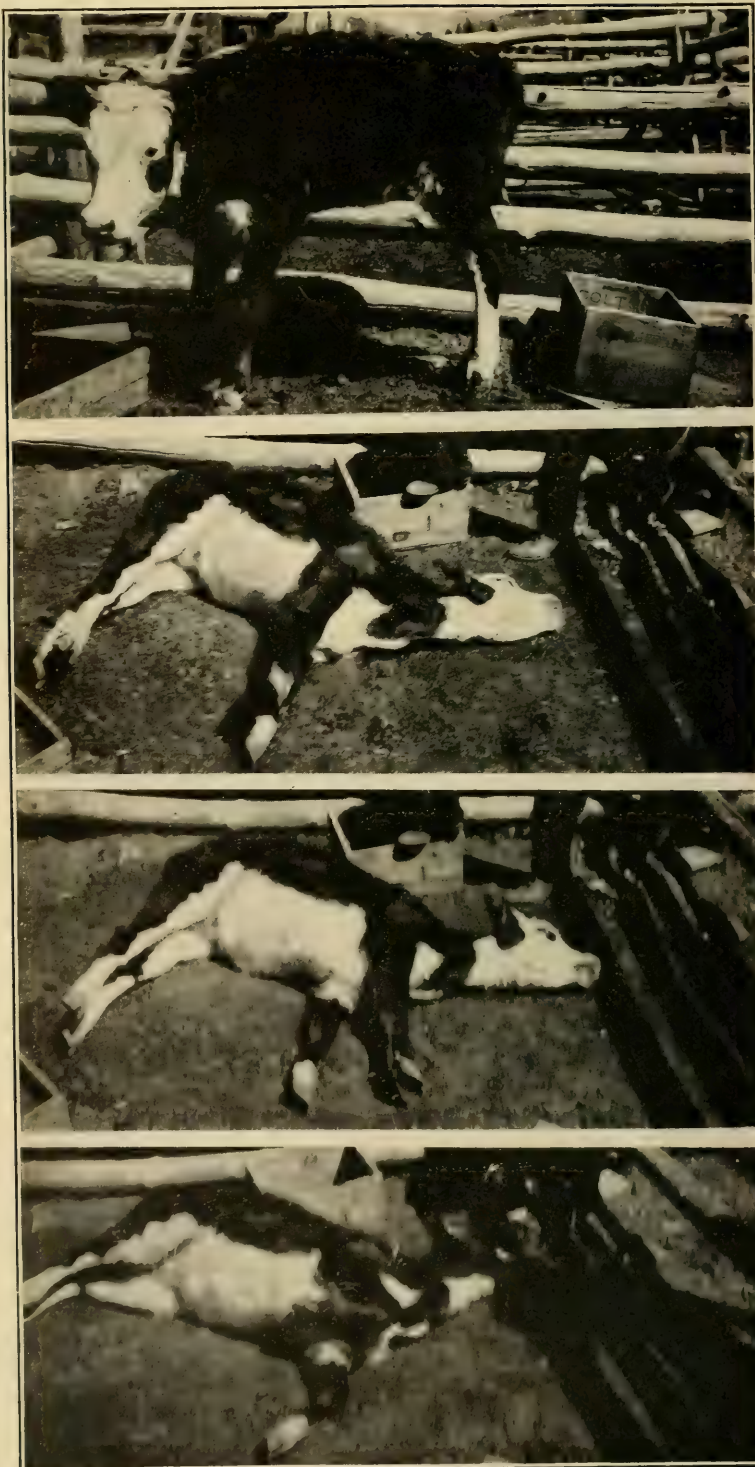
CICUTA VAGANS, SHOWING LEAVES AND FLOWERS.



A YOUNG PLANT OF *CICUTA VAGANS*, SHOWING THE FORM OF THE ROOTSTOCK.



CONIUM MACULATUM, SHOWING LEAVES, FLOWERS, AND FRUITS.



CASE NO. 119 (CALF) AT 10.27, 10.29, 10.37, AND 10.40 A. M.

The woman followed these directions, using one root instead of two. An hour later her husband complained of pain and was nauseated, afterwards falling senseless. Apparently he did not entirely lose consciousness, for he was helped into the home and sat down, but soon fell unconscious and shortly afterwards died, his death occurring about two hours after eating the cake.

It was shown by examination that the root furnished by the fortune teller was that of *Cicuta virosa*.

THE POISONOUS PRINCIPLE OF CICUTA.

When the rootstock of *Cicuta* is cut open, drops of an aromatic oil are noted, which give the root its peculiar odor, and this oil is popularly thought to be the poisonous substance. The poisonous principle, however, is not in the oil but in a resin, and has been separated under the name of cicutoxin and especially studied by Boehm, 1875-76, Wikzowski, 1875, and Pohl, 1894. It has properties similar to picrotoxin and with these two are commonly grouped coriamyrtin, cœnanthotoxin, and santonin.

Kunkel, 1901, p. 934, describes this poisonous principle as a clear brown, sticky resin with an acid reaction, which does not harden when dried. It is soluble in ether, alcohol, chloroform, and dilute alkalis, and is precipitated from alkaline solutions by acids. It is slightly soluble in cold water and more readily in hot water.

Wikzowski, 1875, gives in detail the results of subcutaneous injections of the poison in frogs. His conclusions are as follows:

(1) The poisonous principle of *Cicuta virosa* produces in frogs clonic-tonic convulsions of the whole body and in doses of 4 to 6 milligrams of the ether extract kills with paralysis.

(2) The effect of the poison limits itself to the central nervous system. The activity of the heart and organs of respiration is influenced in a secondary way.

(3) The principal effect of the *Cicuta* poison is upon the "convulsion center" at the end of the medulla oblongata. The upper part of the brain is not affected, while the terminal paralysis of the spinal cord apparently results from the complete exhaustion following the convulsions.

EXPERIMENTAL WORK.

EXPERIMENTS IN COLORADO.

Cicuta occidentalis grew in considerable abundance along the ditches in the irrigated land of Ohio Creek Valley, Colo., at the head of which the Mount Carbon Station was located. The ranchers recognize it as a poisonous plant and some of them make a business of cutting it out. It is never, however, entirely destroyed, and sometimes large quantities of it are cut with the hay.

The experimental work had three objects in view:

- (1) To determine whether the plant was poisonous in summer and early fall.
- (2) To settle definitely the question of the danger to live stock from eating hay containing *Cicuta*.
- (3) To obtain material for verifying and amplifying the description of symptoms and the effects of *Cicuta* poisoning.

This work was carried on in the summers of 1910 and 1911.

FEEDING CICUTA TO SHEEP IN 1910.

In Table I is given a summarized account of the sheep-feeding experiments of 1910. The details of the cases follow. An attempt was made to feed two other sheep, but neither could be induced to eat the material.

TABLE I.—Summary of feeding experiments with *Cicuta occidentalis*, 1910. (Sheep.)

Animal.	Weight.	Amount fed.	Period of feeding.	Part of plant fed.		
	Pounds.	Pounds.				
No. 108.....	100	51.5	Aug. 14 to 23.....	Roots, stems, leaves, and seeds.		
No. 104.....	91	41	Aug. 26 to Sept. 9.....	Roots.		
No. 125.....	100	91	Aug. 26 to Sept. 11.....	Stems, leaves and seed.		
No. 102.....	93	2.5	Sept. 15 to 16.....	Roots.		
No. 101.....	96	(Very little.)	Sept. 15 to 21.....	Do.		
No. 115.....	48	(Very little.)	Sept. 17 to 21.....	Do.		

Animal.	Period of sickness (until able to stand).	Remedy used.	Result.	Ratio of plant fed to weight of animal.	Amount fed to 100 pounds of weight of animal.	Location from which plant fed was obtained.
No. 108.....	Short attack; 35 minutes.	Potassium per-manganate.	Recovery.	1: 1.9	Pounds. 51.5	Sellinger.
No. 104.....	{ About 1 minute..... 1 to 2 minutes..... 23 minutes.....	None.....	do.....	1: 2.3	45	Allison.
No. 125.....			Not sick.....	1: 1.1	91	Do.
No. 102.....			Death.....	1:37.2	2.7	Do.
No. 101.....			Not sick.....			Do.
No. 115.....		do.....	do.....			Do.

CASE No. 108.

Case No. 108, a wether weighing 100 pounds, was taken out of the pasture on the night of August 12 for feeding with *Cicuta*. The feeding was commenced at 11.30 a. m. on August 14, when he was given ground tubers of *Cicuta occidentalis*. During the day he ate very little except what he got accidentally in picking out oats that had been thrown upon the ground material. On the morning of August 15 he was given an additional quantity of *Cicuta* roots, this being mixed with hay with the feed that had remained from the preceding day. Apparently very little of this was eaten except what was obtained accidentally in connection with taking the hay, but by the night of August 16 he had eaten a considerable amount of roots. On August 17 he was fed stems and tops of *Cicuta*, the plant being in seed. This was entirely eaten up with what remained of the *Cicuta* roots by the night of August 17. On the morning of August 18 more of the ground roots was fed with cut hay and it was all eaten. Because of lack of material he was not fed on August 19. On August 20 and 21 he

was fed stems, leaves, and seeds. Up to this time no effects had been noticed from the feeding.

On the morning of August 22 he was again given ground Cicuta roots in cut hay, receiving at this time 2 pounds. At 12.30 noon, the animal was found down and apparently unable to get up when disturbed, but when raised to his feet was able to stand. He frothed a little at the mouth. About 15 minutes later he appeared to be all right and ran about the corral actively. No further symptoms were noticed on this day.

On the morning of August 23, at 8.30 a. m., this sheep was given 5 pounds of ground Cicuta roots in cut hay. At 6.30 p. m. he was found lying down on his side with legs extended and with head raised and turned to one side. His eyes were turned down, showing the white above the iris. His breathing was rapid and noisy, groans accompanying the expirations. When raised on his legs he stood for a minute with hind legs braced apart and stretched out behind, then trembled violently and fell, acting as if he were choking. Potassium permanganate and aluminium sulphate were administered in a drench, although it was difficult to make him swallow. He kept his mouth closed tight and ground his teeth together. At 6.45 his pulse was 176. At 7 his respiration was 62, apparently growing slower. At 7.05 he got upon his feet with assistance and stood with his legs braced apart. His pulse was 180, full and strong. At 7.08 his respiration was 46 and the groaning had ceased. At 7.15 the pulse was 168 and respiration 26. At 7.20 his pulse was 168. Some of this time he remained on his feet, gradually growing stronger, and at 8.30 had walked a few steps. At that time he was stupid and weak. When he walked he staggered and dragged his hind feet. His pulse was 84, respiration 20.

On the morning of August 24, while somewhat weak and uncertain on his feet, he appeared fairly well and was turned into the pasture, showing no further symptoms. His weight at that time was 91 pounds, showing that in the course of the experiment he had lost 9 pounds. On the last day of the feeding, August 23, of the 5 pounds of Cicuta roots he had eaten about $3\frac{1}{2}$ pounds.

The impression from the experiment was that the stems, leaves, and seeds had been fed without effect and that the poisoning was directly the result of feeding the roots on August 23.

CASE No. 104.

Case No. 104 was brought in from the pasture for Cicuta feeding on August 24. This wether weighed 91 pounds at 6 p. m. on August 25. Feeding was commenced at 9.50 a. m., August 26, when he was given $2\frac{1}{2}$ pounds of ground Cicuta roots mixed with a pound of cut hay. He did not eat readily, but during the day disposed of perhaps two-thirds of the amount fed in the morning.

On August 27 part of the feed remaining was removed and more was supplied in cut hay. Feeding was carried on in this manner through August 28, 29, 30, and 31. During the day of August 31 he had eaten all the Cicuta supplied and was given some additional hay.

On September 1, the supply of Cicuta being exhausted, he was fed hay. The feeding of the ground roots was resumed on September 2 and continued until the morning of September 8 before any results were noted.

At a little after 10 a. m., September 8, the animal was found down, apparently in a fit. He was able to get up, however, without assistance. He frothed at the mouth and was weak in the hind legs, but was able to run about. When down he kicked about convulsively. At 10.20 his pulse was 80 and fairly strong. At 10.25 he had apparently recovered and showed no further marked symptoms. He had eaten very little of the material fed, and the poisoning apparently resulted from the feeding of the preceding day.

On the morning of September 9 the uneaten material was removed and at noon he was given 4 pounds of fresh-ground *Cicuta* roots with a half pound of cut hay.

At 5.55 p. m. he was found down on his left side, kicking convulsively and unable to rise. When raised to his feet, however, he walked to the side of the corral. Respiration was 28 and rather deep. He was fairly strong and able to run about the corral rather actively, so it was difficult to take his pulse. From the time he was found down and helped up he showed no marked symptoms except weakness and uncertain movements of his head. He appeared abnormally excitable, starting at the slightest sound or movement, sometimes giving a sudden start without apparent cause. At 6.55 p. m. he was found down again. He was lying on his belly and unable to rise. His temperature was 102.5°; pulse, 128. At 6.56 he had a convulsion with opisthotonos, followed by violent kicking of the fore and hind legs, rolling over on his side. At 6.58 he managed to rise; his pulse was 132; his head moved about in a spasmodic way, resembling hiccoughs, and suggested spasmodic contractions of the diaphragm. At 7 he was standing with his legs braced apart, unable to walk. His pulse was 172. At 7.06 he fell down again and went into a violent convulsion, more severe than the preceding. His head was drawn up, with his chin against the breast, apparently held by a violent muscular contraction. He then rolled over upon his side with the head thrown back. This was followed by violent movements of his legs and head. Then he lay upon his belly, his legs doubled under him and the hind legs extended. His breathing was labored and the hiccoughing or spasmodic jerking of the sides and head continued. At 7.09 he was still on his belly and unable to rise. His pulse was 180. He was raised to his feet. When his shoulders were raised he fell again, but when his hind quarters were raised he managed to get up, or, in other words, apparently he was especially weak in his hind legs, but was able to use his fore legs. At 7.20 he was able to walk a little when urged. At 8 he was still on his feet and able to walk about, but weak in his hind legs. His pulse was 140 and rather strong. He passed a large quantity of urine. He occasionally belched gas and ground his teeth. The hiccoughing had practically stopped.

From this time on there were no noticeable symptoms, and on the morning of September 10 he was turned back with the band in the pasture. He weighed at the time 86 pounds, showing that during the feeding he had lost 5 pounds. All told, he had eaten 45 pounds of roots. It is to be noted, however, that the feeding was continued over quite a long period and that the poisoning may be considered to have resulted from a comparatively small amount eaten within a short time.

CASE No. 125.

Case No. 125 (a wether) was brought in for *Cicuta* feeding on August 24. This sheep weighed 100 pounds at 6 p. m. on August 25. Feeding was commenced at 10 a. m. on August 26, when it was given leaves, stems, and seeds of *Cicuta*. This feeding was continued during August 26 and 27. Because of lack of material none was fed on August 28 and 29, but the feeding was resumed on August 30. Because of lack of material no more was fed on August 31 and September 1, but the feeding was resumed on September 2 and continued to September 12.

The animal ate with fair readiness the fresh young leaves and succulent stems, but objected to the dried material, and it was rather difficult to make it clean up the stems and the seed tops. Up to August 30 fresh plants were fed, the seeds being rather green. From September 2 to 6 the material was dry and was eaten less readily. From September 7 to 11 the material was fresher, but the seed tops were past maturity. It is estimated that in the course of the feeding the animal ate 91 pounds. The plant produced no toxic effect and the sheep was turned out on September 12, apparently in good condition. It weighed at this time 94 pounds, having lost 6 pounds in the course of the experiment.

It should be noted that the feeding was rather desultory in character and was extended over such a long time that it could not be considered as a conclusive experiment as to the tops, although the impression among the observers was that the tops were not injurious.

CASE No. 102.

Case No. 102 was brought in for feeding with *Cicuta* on September 14. At 8 p. m., September 15, this wether weighed 93 pounds. At 2.05 p. m., it was fed 1 pound and 9 ounces of ground *Cicuta* roots. On the morning of September 16 it was given a little hay, mixed with the *Cicuta* which remained from the feeding of the preceding day. At 5.50 a. m. it was given 1 pound and 10 ounces of ground *Cicuta* roots and at 9 p. m. was found dead in the corral. It had eaten, all told, in the two days 2 pounds and 8 ounces, or on the basis of 100 pounds of weight $2\frac{7}{10}$ pounds.

This sheep was autopsied on the morning of September 17. It was bloated; there was opisthotonos; it had frothed at the mouth and had evidently kicked about in the corral. It was lying on the left side. The surface of the heart was congested. The left ventricle was contracted and the right ventricle dilated. The lungs were strongly congested, and the inner walls of the trachea and the bronchi inflamed. The walls of the lower part of the ileum and cecum were inflamed. The brain and the membranes of the spinal cord were congested. A piece of the kidney was preserved and sectioned. It showed strong congestion. In the medullary portion the walls of the tubules were in good condition, and the blood was confined to the vessels and was not broken down. In the cortical portion the walls of the tubules were degenerated to some extent. The blood was very abundant and was all through the tissue, not being confined to the vessels. In the cortex a large part of the red corpuscles were "ghosts," the pigment having been broken down and appearing outside the corpuscles in the form of granules. The blood vessels of the tissue of the kidney contained some very large bacteria, probably putrefactive organisms. The conclusion is that this condition of the cortex is due to a combination of an acute nephritis and post-mortem decomposition. A piece of liver was also embedded and sectioned. The liver contained a great deal of blood, most of which was hemolyzed and broken down. The liver cells seemed to be normal. Large numbers of bacteria similar to those found in the kidney were present in the liver.

FEEDING CICUTA TO CATTLE IN 1910.

CASE No. 119.

Case No. 119, a heifer weighing 300 pounds, was brought in September 13 for feeding with *Cicuta*. The animal at that time was in good condition. Feeding was commenced at 8.30 a. m. on September 14, when she was given three roots, to see whether she would eat the plant. At 9.10 a. m. she was fed 1 pound and 5 ounces of the whole roots. At 10.20 a. m. she was found on the ground in a fit. The animal got up, but soon went down again in a violent spasm. She kicked, straightening her legs rapidly, extended her head, and frothed at the mouth, emitting an occasional bellow. She staggered about the corral in a dazed way and went down, kicking violently. An attempt was made to give her a drench of magnesium sulphate and tannin, but her struggles were so violent that it was impossible. A series of photographs taken between 10.27 and 11 show the condition and attitudes assumed. (Pl. IV.) At 10.35 she was given three grains of morphin hypodermically. At 10.45 the struggles were somewhat less violent, perhaps because of exhaustion, and at 10.50 she died.

An autopsy was made immediately. The skin was very much congested, the teats being violet purple in color. The surface of the heart was congested, the left ventricle contracted, and the right expanded, with slight congestion on the inner wall. The lungs and inner walls of the trachea and bronchi were congested. The walls of the anus were inflamed, the kidneys were congested, the brain slightly congested, and the membranes of the spinal cord somewhat congested. The omentum had spots of

inflammation 2 or 3 inches across. The lower part of the small intestine was deeply inflamed. The general condition of the circulatory system would indicate that the animal died from respiratory failure. The section of the kidney prepared for microscopic examination showed very great congestion, especially in the cortical portion, where portions of the convoluted tubules appeared somewhat degenerated. The blood vessels and some of the spaces outside the veins were filled with red corpuscles.

CASE No. 121.

Case No. 121 was a yearling, weighing about 300 pounds. He was brought in for feeding with Cicuta on the evening of September 8. Feeding was commenced at 9.15 a. m. on September 9, when he received $2\frac{1}{2}$ pounds of whole roots. At noon it was noticed that he was not eating readily. The material had been mixed with cut hay and he had eaten a few of the roots. He was somewhat salivated at this time. Feeding was repeated at 6 p. m. On September 10 he was fed at 10.30 a. m., and at 6 p. m. he was frothing somewhat at the mouth. At this time a large portion of his food had not been eaten. On September 11 he was fed more hay, in order to induce him to clear up the Cicuta, and additional Cicuta was ground and mixed with moist cut hay to induce more complete feeding. This feeding was at 10.15 a. m. At 12 noon he was found salivated, breathing with a peculiar contraction of the nares and elevation of the corners of the mouth.

While the station force was at supper a sound was heard of an animal apparently in distress. This animal was found down on its side, but immediately got up. This was about 7.50 p. m. He walked about uneasily, jerking his head more or less as though having hiccoughs. His pulse was 50 and full. Suddenly he commenced to back, jamming himself first against one side of the corral and then against another, his muscles contracting violently. He went into a fit and fell, the head going down first. He kicked violently and frothed at the mouth. The violent kicking gradually subsided. At 8.05 his pulse was 112 and the breathing was labored and noisy. At 8.08 his pulse was 73 and his respiration 36. At 8.15 the breathing was quieter, the respiration 32.

A little before this he raised himself and lay on his belly with his fore legs doubled under him. Immediately afterwards his eyes were turned in, he struggled convulsively, turned himself about, and fell upon his side, but raised himself again upon his belly. At 8.20 he raised himself again, coming back upon his belly. At 8.22 he had another spasm, going through the same motions. At 8.25 he went into a violent fit. There was marked opisthotonos. He kicked violently, his legs stiffened, standing out rigidly from the body. He frothed at the mouth and was in a strong perspiration.

At 8.30 his pulse was 142. The fit continued, its violence, however, varying. At 8.45 he was given hypodermically a quarter of a grain of strychnin. This was administered in the midst of a fit and he died almost immediately, before the strychnin could have had any effect. Death was caused apparently by respiratory failure, as the action of the heart continued an appreciable time after respiration ceased.

An autopsy was held on September 12. The right auricle was much congested and full of blood. The inner wall of the right ventricle was deeply congested. This ventricle contained little blood and was partly contracted. The left auricle and ventricle contained little blood and were not congested. The wall of the first stomach at the pyloric end was deeply inflamed, as was the wall of the second stomach. On the wall of the fourth stomach were a few inflamed spots. Through the length of the small intestine there were small spots of congestion, while the lower part of the ileum was deeply inflamed. The rectum was somewhat inflamed. The kidneys were congested. The brain was congested, as well as the membranes of the spinal cord. Microscopical section of the kidney showed great congestion, especially in the cortical portion. Portions of the walls of the tubules were degenerated. A great many of the blood corpuscles were broken and stained only very lightly, while through the whole

section were granules which did not stain and were probably broken-down blood pigment. The blood vessels also contained bacteria. This animal ate, all told, approximately 10½ pounds, or, on the basis of 1,000 pounds of weight, 35 pounds of *Cicuta*.

Table II gives a summarized statement of these feeding experiments.

TABLE II.—*Summary of feeding experiments with Cicuta occidentalis, 1910. (Cattle.)*

Animal.	Weight.	Amount fed.	Date or period of feeding.	Part of plant fed.
	<i>Pounds.</i>	<i>Pounds.</i>		
No. 119.....	300	1.5	Sept. 14.....	Roots.
No. 121.....	300	10.5 (?)	Sept. 9 to 11.....	Do.

Animal.	Remedy used.	Result.	Ratio of plant fed to weight of animal.	Amount fed to 1,000 pounds of weight of animal.	Location from which plant fed was obtained.
				<i>Pounds.</i>	
No. 119.....	None.....	Death.....	1 : 200	5	Allison.
No. 121.....	do.....	do.....	1 : 28.5	35	Do.

EXPERIMENTAL WORK OF 1911.

The feeding experiments of 1911 were made to determine whether the tops and seeds of *Cicuta* are poisonous.

Table III gives a summarized statement of the cattle experiments, the details of which follow.

TABLE III.—*Summary of feeding experiments with Cicuta occidentalis, 1911. (Cattle.)*

Animal.	Weight of animal.	Amount fed.	Period of feeding.	Part of plant fed.
	<i>Pounds.</i>	<i>Pounds.</i>		
No. 641 ..	450	76.5	July 26 to 28.....	Leaves, stems, and flowers, with chopped hay.
No. 648 ..	500	133	July 30 to Aug. 2	Leaves, stems, flowers, and some seed.

Animal.	Period of sickness (until able to stand).	Remedy used.	Result.	Amount fed to 1,000 pounds of weight of animal.	Location from which plant fed was obtained.
				<i>Pounds.</i>	
No. 641.....	None.....	None.....	None.....	170	Near Castleton.
No. 648.....	do.....	do.....	do.....	266	Do.

Two head of cattle, Nos. 641 and 648, were fed. No. 641 during the three days from July 26 to 28 received, per 1,000 pounds of weight, 170 pounds of leaves, stems, and flowers of *Cicuta*. This was fed with a little hay in order to induce the animal to eat it more readily. No. 648 during the four days from July 30 to August 2 received 266 pounds of leaves, stems, flowers, and some seed of *Cicuta*. Neither of these animals suffered any ill effects from the feeding.

The more extended feeding of the summer was done in the case of sheep. Table IV shows a summary of these experiments. In addition to the thirteen animals listed in the summary, two (Nos. 145 and 152) were brought in for feeding, but ate so little that they are not included in the sum total of the summer's work. Five of the sheep (Nos. 136, 137, 149, 151, and 158) were fed upon the leaves and stems of *Cicuta* and received, per 100 pounds of weight, from 11.4 pounds, in the case of No. 137, to 143.3 pounds, in the case of No. 158. These amounts were fed in periods varying from one week to about ten days. None of the animals suffered any ill effects from the feeding, although in the case of No. 158 it ate of the plant nearly 50 per cent more than its weight. In all of these cases the sheep were fed exclusively upon the leaves and stems, with the exception of one or two cases, like No. 136, where a little hay was mixed with the material in order to induce the animal to eat it more readily. Nos. 157 and 143 were given leaves, stems, and flowers, mixed with enough hay to induce them to eat it more readily. No. 143 in eleven days ate 16.5 pounds per 100 pounds of weight, while No. 157 in ten days ate 109.1 pounds, or just about the equivalent of its weight. Neither of these animals suffered any ill effects.

TABLE IV.—Summary of feeding experiments with *Cicuta occidentalis*, 1911. (Sheep.)

Animal.	Weight.		Amount fed.	Date or period of feeding.	Part of plant fed.
	Before.	After.			
	Pounds.	Pounds.	Pounds.		
No. 136...	153	-----	19.5	June 17 to 22.....	Leaves and stems.
No. 137...	153	-----	17.5	do.....	Do.
No. 149...	100	-----	52	June 24 to 30.....	Do.
No. 151...	122	-----	50	do.....	Do.
No. 157...	109 ¹	-----	119.5	July 8 to 18.....	Leaves, stems, and flowers.
No. 143...	122 ¹	120	20.25	July 8 to 19.....	Stems and flowers.
No. 158...	101 ¹	-----	145.5	July 9 to 19.....	Leaves and stems.
No. 144...	103	98	54.5	August 5 to 12.....	Young seed and seed stems.
No. 135...	136	127	2.2	August 16 to 17.....	Young seed.
No. 142...	117	100	2.65	August 19.....	Seed.
No. 148...	137	130	11.5	August 19 to 23.....	Young seed and seed stems.
No. 151...	122	-----	4.4	August 26.....	Seed.
No. 140...	115	106	4.4	August 30.....	Do.

Animal.	Period of sickness (until able to stand).	Remedy used.	Result.	Amount fed to 100 pounds of weight of animal.	Location from which plant fed was obtained.
				Pounds.	
No. 136...	None.....	None.....	None.....	12.7	Near Castleton.
No. 137...	do.....	do.....	do.....	11.4	Do.
No. 149...	do.....	do.....	do.....	52	Do.
No. 151...	do.....	do.....	do.....	41	Do.
No. 157...	do.....	do.....	do.....	109.1	Do.
No. 143...	do.....	do.....	do.....	16.5	Do.
No. 158...	do.....	do.....	do.....	143.3	Do.
No. 144...	do.....	do.....	do.....	52.9	Near Hinkle's.
No. 135...	do.....	do.....	do.....	1.6	Do.
No. 142...	(One spasm?).....	do.....	Recovery.....	2.3	Do.
No. 148...	None.....	do.....	None.....	8.4	Do.
No. 151...	do.....	do.....	do.....	3.6	Do.
No. 140...	do.....	do.....	do.....	3.8	Do.

¹ Estimated.

Two sheep, Nos. 144 and 148, were fed upon the seeds and seed stems, No. 148 eating 8.4 pounds per 100 pounds of weight and No. 144 receiving 52.9 pounds, or about one-half its own weight. This latter quantity was fed in about a week's time. These animals suffered no harm.

In order to make certain that a large amount of the seeds was taken in a short time, four animals were drenched with the seeds ground up and mixed with enough water to make it possible to administer them in this manner. No. 135 received in two days 1.6 pounds of seed, No. 142 in one day received 2.3 pounds, No. 151 in one day received 3.6 pounds, and No. 140 in one day received 3.8 pounds. Of these animals No. 142 was the only one that sustained any harm.

No. 142 was brought in for feeding on August 18, 1911, weighing at that time 117 pounds. On August 19, at 9.50 a. m., it was given, in a drench with about $1\frac{1}{2}$ quarts of water, 200 grams of ground *Cicuta* seed. This dose was repeated at 11.15 a. m., 1.50, 3.00, 7.30, and 9.30 p. m. This sheep was given a little hay on August 20, and on August 21, when an attempt was made to turn it out of the corral, it ran part way round the corral, stood, and leaned against the fence, trembling all over. It moved to another part of the corral, and fell there, with the head thrown back, and went into convulsions. These lasted about one minute. The teeth were grated and the muscles contracted. It soon got up, but appeared for several minutes as though dazed. It breathed rapidly for a time and some trembling was noticed for about 15 minutes. The next day, however, it appeared to be all right.

The symptoms were so much like *Cicuta* poisoning that this condition was considered as due to the effect of the *Cicuta* seeds, although the poisoning was strangely delayed. None of the animals suffered any harm from the material which they received as a drench.

GENERAL CONCLUSIONS.

SYMPTOMS OF CICUTA POISONING.

Perhaps no better description of *Cicuta* poisoning has ever been written than that given in 1679 by Wepfer, who tells how children after eating the roots returned home "laeti," one of the little girls tearfully complaining of the selfishness of the others in not giving her her share of the root; he then goes on to tell the symptoms exhibited by each of the children. The following is his description of one case:

Jacobus Maeder, puer sex annorum, capillis albis praeditus, tener vegetus tamen, domum rediit hilaris ac subridens, quasi re bene gesta: paulo post conquerebatur, de praecordiorum dolore & vix verbum effatus, humi prostratus urinam magno impetu ad

Viri altitudinem eminxit: mox terribili aspectu, cum omnium sensuum abolitione convulsus fuit, os arctissime clausit, ut nulla arte aperiri valuerit, dentibus stridebat, oculus mire distorquebat, sanguis ex auribus promanabat: circa praecordia tumidum quoddam Corpus pugni virilis magnitudine, Patris afflicti manum & miserandi Pueri praecordia, maxime circa Cartilaginem ensiformem, validissime feriebat: singultiebat crebro: Vomiturus quandoque videbatur, nihil tamen ore arctissime clauso ejicere valuit: artus mire jactabat & torquebat, saepius caput retrorsum abripiiebatur, totumque dorsum incurvabatur in arcum, ut puellus subtus per spatium inter dorsum & stratum inoffense repere potuisset. Cessantibus convulsionibus per momentum matris opem imploravit: mox pari ferocia illis redeuntibus nulla vellicatione, nulla acclamatione, nullo alio ingenio excitari poterat, donec viribus deficientibus expalluit, & manu pectori admota exspiravit. Durarunt haec Symptomata vix ultra horam dimidiam.

Not only is this a vivid and accurate description of the symptoms of *Cicuta* poisoning, but it has a touch of pathos in the call of the child for assistance from his mother.

Since the time of Wepfer a large number of descriptions of the symptoms of this form of intoxication have been written, most of them being cases of the poisoning of man. There is great uniformity in these descriptions, the difference being mainly in the greater or less stress laid upon particular phases of the symptoms. In minor particulars there has been some contradiction, but this is no more than would be expected, for it is inevitable that among such a large number of observers some would make inaccurate statements.

The symptoms of the lower animals are like those in man, only less marked because of the less susceptible nervous system.

The generally recognized symptoms are as follows:

Pain, especially in the region of the stomach; but it may be quite general in character.

Nausea, leading sometimes to violent vomiting; at others, to spasmodic attempts at vomition without result.

Generally diarrhea and polyuria.

Dilated pupils.

Labored, stertorous breathing, at times irregular.

Sometimes, frothing at the mouth.

Pulse weak, intermittent, and rapid.

Temperature observations have been made in only a few instances, probably due to the fact that most of the recorded cases occurred before the use of the clinical thermometer was common among medical men. According to French, 1866, there is elevation of temperature.

The convulsions are most violent, both tetanic and clonic, accompanied by gnashing of the teeth and trismus, and in violent cases, as in Wepfer's story, by opisthotonos. These convulsions may be accompanied or followed by unconsciousness, and in fatal cases grow more violent until ended by death.

The observation of the cases at Mount Carbon added little to what was already known in regard to the symptoms, but gave a more complete picture.

Excessive salivation, "frothing at the mouth," was generally the first symptom noted, and this occurred in the mild cases. It was followed or accompanied by uneasiness and pain. The animal soon fell in a violent convulsion. Peculiar spasmodic contractions of the diaphragm occurred before and after falling. The convulsions were most violent. The animal would kick, sometimes extending the legs rigidly. It would throw back the head, sometimes with marked opisthotonos, and would bellow and groan as though in great pain. The pupils were dilated and the eyes sometimes turned in or down.

The pulse was weak and rapid, running as high as 180, and respiration was noticed as high as 62.

Gnashing of the teeth and convulsive closing of the jaws were noticed in the Mount Carbon cases.

The convulsions were intermittent and increased in violence in the fatal cases.

In those that recovered there was a gradual slowing of the pulse and respiration.

So far as the observations went there was no change in temperature.

This train of symptoms is so pronounced and so different from those produced by any other poisonous plant in the temperate regions that a diagnosis of *Cicuta* poisoning is positive and easily made.

AUTOPSY FINDINGS.

A considerable number of autopsies upon man and the lower animals have been reported. Nearly all reports agree as to finding a hyperemia of the brain and central nervous system. Several found inflammation of the walls of the stomach and a fluid condition of the blood. This lack of coagulation of the blood was reported by Wepfer, 1687, and has been noticed repeatedly since that time. Trojanowsky, 1874, says that the poison is antiseptic, as evidenced by the delayed process of decay.

Velten, 1839, found inflammation of the larynx, trachea, and bronchial tubes, and French, 1897, and Nevermann, 1912, reported congested lungs.

Some writers have reported more or less inflammation of the mucous membrane of the stomach.

Three autopsies were made at Mount Carbon—two upon cattle and one upon a sheep. These autopsies confirmed the reports of previous observers, and some additional facts were noted. The left ventricle was contracted and the right dilated, while the walls of the heart were more or less congested. The most marked feature was the extreme congestion of the venous blood vessels. The lungs,

kidneys, and membranes of the central nervous system showed strong congestion. The mucous membrane of the trachea and bronchi was inflamed, as were also the inner walls of the small intestine and stomach and in some cases other parts of the alimentary canal.

In the kidneys the congestion was most marked in the cortex and was accompanied with some nephritis. It was noticed that the red blood corpuscles in the kidneys were more or less broken down. Death resulted from respiratory failure.

TOXIC DOSE.

Very little has been known in regard to the toxic dose of *Cicuta* beyond the fact that only a small quantity is necessary to produce poisonous effects.

Stockbridge, 1814, says that in a fatal case about 1 dram was eaten. Hedrick, 1897, states that a piece the size of a walnut was found by experiment to be sufficient to kill a cow. Other similar estimates have been made, all more or less indefinite. In cases of accidental poisoning it is very difficult to estimate how much has been eaten, and there has been little exact experimental work. About all that has been known is that the rootstock is extremely poisonous and that fatal results have followed the eating of very small quantities.

The experimental work at Mount Carbon gave very little definite information in regard to the toxic dose. The sheep that died ate in two days 2.7 pounds per hundred pounds of weight. From the records, two other sheep which became sick apparently ate a very large quantity of the roots, but the circumstances of the feeding indicate that the actual poisoning was produced by a comparatively small quantity. Heifer No. 119 died as the result of eating 5 pounds per 1,000 pounds of weight in a single day. These deaths occurred at a time when, as stated elsewhere, there is reason to think that the *Cicuta* is not as poisonous as at other seasons.

All that can be said definitely is that a very small quantity of the root of *Cicuta* may produce death, but the amount varies with the season and also with the period of time during which it is eaten.

ANIMALS POISONED BY CICUTA.

It is probable that most, if not all, of the higher animals may be poisoned by *Cicuta*.

Wepfer, 1679, showed experimentally that dogs, wolves, and birds could be poisoned.

Gadd, 1774, says that horses, oxen, cows, and goats are poisoned.

Krause, 1837, describes a case of poisoning of horses and gave details of some experimental work which seemed to corroborate the correctness of his diagnosis.

Oeltze, 1837, and Scholler, 1853, give specific instances of the poisoning of swine.

It has been repeatedly stated in literature that sheep and goats are not affected; where this statement originated is not clear.

Bulliard, 1784, page 99, says that goats eat *Cicuta* without harm. Gray, 1821, page 508, says that it is poisonous to mankind and kine, but not to horses, sheep, or goats.

Rafinesque, 1828, page 109, states that "sheep and goats eat them [*Cicuta* plants] with impunity, and even cattle do not appear injured by them when mixed with hay."

Kunkel, 1901, page 935, says that goats and swine are not poisoned, but that horses and all carnivorous animals are very susceptible.

Instances of the poisoning of swine are so specific and given in such detail that we can hardly question their accuracy.

Chesnut, 1901, and Chesnut and Wilcox, 1901, tell of cases of poisoning of sheep in Montana, and the experimental work of the Mount Carbon Station, already detailed, gives conclusive evidence that sheep are affected by *Cicuta*.

In regard to goats there appears to be no record of definite cases. It does not seem very probable, however, that these animals are immune to *Cicuta* poisoning.

It will appear later in this paper that *Cicuta* tops are not poisonous or do not possess enough of the poisonous principle to affect cattle and sheep, and it seems possible that the stories of the immunity of goats may have arisen from cases in which the tops only were eaten and no harmful results followed.

WATER POISONED BY CICUTA ROOTS.

Gadd, 1774, related in some detail a case of poisoning of cattle from drinking water in which were *Cicuta* roots. Since that time a number of authors have made the statement that cattle trampling the roots along bodies of water from which they drink have rendered the water poisonous. While this may be possible, the evidence does not seem very conclusive.

THE PART OF THE PLANT WHICH IS POISONOUS.

There seems to have been some difference of opinion as to whether or not the whole plant of *Cicuta* is poisonous. There is a general consensus in regard to the toxic properties of the root, but authorities are contradictory in their statements about the stems and leaves.

Gadd, 1774, states that the poison is mostly in the root and lower leaves.

Rafinesque, 1828, page 109, says that "even cattle do not appear injured by them [the stems and leaves] when mixed with hay."

Schünemann, 1891, says "die ganze Pflanze ist sehr giftig."

Krause, 1837, gives the details of the supposed poisoning of horses by *Cicuta* in hay. He fed the stems and leaves experimentally to three horses. All became sick and two died.

Hedrick, 1897, says "it is probable that the poisonous constituent is found only in the underground stem and the roots."

Ladd, 1899, states that the roots and seeds are especially poisonous and that the tops are poisonous in hay.

Brodie, 1901, experimenting with *Cicuta vagans*, fed all parts of the plant in May, July, and August without results, but killed an animal in November after the stems and leaves were dead.

Chesnut and Wilcox, 1901, page 82, speaking of *Cicuta occidentalis*, say:

Field observations indicate that leaves and stems, including the basal portion of this plant, at least during the early stages of growth, contained sufficient poison to produce death. The roots contain a virulent poison.

Blankinship, 1903, page 89, states that the roots and foliage are more poisonous in early spring and that cases are reported of poisoning from eating "slough hay." It is to be presumed that these latter cases were poisoned by the tops.

It appears, therefore, that the preponderance of opinion, we can hardly say evidence, is in favor of the whole plant being poisonous. This subject is discussed in the experimental part of this paper (pp. 15-17).

The feeding experiments at Mount Carbon show that there is little danger, if any, from the aerial parts of the plant. In 1911, *Cicuta* tops, from the time they were 8 inches to a foot in height until maturity, were fed to sheep with no ill effects. The quantity fed was many times that which would be taken in grazing. It is possible that just as the plants are starting to grow the shoots may be harmful, but it seems more probable that at times the animals poisoned get some of the rootstock. In the experimental work with seeds the animals were drenched with 1.6 to 3.8 pounds of seed to 100 pounds of their weight and only one animal showed symptoms of poisoning. This quantity of seed is evidently vastly more than a sheep could obtain in hay.

It seems clear, then, that hay containing *Cicuta* tops and seeds is harmless, and that practically the only danger from the plant is from ingestion of the roots.

SEASON WHEN CICUTA IS MOST POISONOUS.

It is generally stated that the plant is most poisonous in the spring. Some authors say that as the stored material of the rootstock is used up in the growth of the plant, it ceases to be poisonous. Certainly most cases of poisoning occur in the spring.

Hedrick, 1897, pages 7 to 9, gives notes of experiments of Prof. French in feeding roots of *Cicuta vagans* in March. One 2-year-old heifer died in an hour and a half from eating not more than 2 drams of one root. Another one was fed "two bulbs the size of an egg" and died in two hours and a half. The bulbs were kept growing in a greenhouse, and feeding experiments conducted early in May, in which several times the quantity used in March produced no ill effects. This seemed to prove conclusively that the roots diminish in toxicity as the growth progresses.

The experimental work at Mount Carbon gave very little exact information in regard to this. The feeding of roots occurred from the middle of August until September 21. Of the sheep, two were made sick and one died. The two cattle experimented upon died. In all cases the quantity eaten was considerably more than that reported by others as poisonous in the spring. The smallest quantity was in the case of No. 119, which ate five pounds per 1,000 pounds of weight, September 14. Of course, at this season, the middle of September, the plant is mature, and if the toxic principle accumulates in the rootstock it might be expected to be as poisonous as in the spring unless some chemical change takes place during the winter. The experiments in August indicate that the roots are poisonous at that time. It seems probable that they are poisonous at all times of the year, but that the toxicity is very much diminished during the growing season of the plant.

REMEDIES FOR CICUTA POISONING.

It was noticed by the older authors that when the eating of *Cicuta* was followed by vomiting, the patient usually recovered. The logical remedy, then, is an emetic, and when this is given promptly with the first symptoms the prognosis is favorable. What is known of the poisonous principle, cicutoxin, would indicate that it is probably dissolved in the stomach slowly and with some difficulty, and that prompt evacuation of the stomach may remove most of the trouble. The emetic is logically followed by a cathartic to facilitate elimination.

When the convulsions are violent, some form of opium may be given to control them, but the main reliance must be upon the emetic. This has been the treatment used through the whole history of *Cicuta* poisoning, and no change has been made in modern times beyond the use of more efficient means of emptying the stomach.

In the practical handling of poisoned live stock little can be accomplished in the great majority of cases. The convulsions are so violent that it is difficult to give any remedy *per os*.

Chesnut and Wilcox, 1901, page 85, recommend hypodermic injections of morphin to control the convulsions, giving sheep 1½ grains and cattle and horses 3 to 10 grains. This may assist in

bridging over the period of convulsions, and doubtless a purgative would help in carrying off the effects of the poison. Most cases, however, are hopeless, and to reduce the losses attention should be paid to the obvious methods of prevention rather than to any remedies.

SUMMARY.

(1) The poisonous properties of *Cicuta* have been recognized since the middle of the seventeenth century, and a large number of cases of poisoning of men and animals have been reported.

The toxic principle has been separated and its properties determined. This toxic principle is probably common to all species and there is reason to think that all species are equally poisonous.

(2) There is a definite train of symptoms, marked by nausea, pain, and violent convulsions, which makes it easy to diagnose cases of *Cicuta* poisoning.

The prominent lesions, as found in autopsies, are congestion of the lungs, kidneys, and central nervous system, with inflammation of the alimentary canal.

(3) So far as known, all the higher animals are poisoned by *Cicuta*.

(4) The quantity necessary to poison is very variable, depending probably on the stage of growth. The plant is very poisonous at all times.

(5) The toxic principle is largely confined to the rootstock. The tops under ordinary circumstances are not poisonous, and neither the tops nor the seeds when found in hay are a source of danger.

(6) The best remedy is an emetic. Very little can be done for poisoned live stock.

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(PROFESSIONAL PAPER.)

IMMUNIZATION TESTS WITH GLANDERS VACCINE.

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INTRODUCTORY.

Among the diseases of horses with which the veterinary authorities are concerned glanders is probably the most important, and unless strict measures for its control are enforced the tendency of the disease is to spread more or less rapidly. This fact is due to the character of the disease, to the prevailing methods of caring for horses, and, probably more important than all, to the frequent latent existence of the disease in apparently healthy animals. The destruction of all infected animals has been accepted as a matter of course in all civilized countries, and owing to the dangerous character of the disease and the possibility of transmission to man, this action appears to be the sanest and most reasonable procedure in its control. On the other hand, the possibility of a method of immunization of healthy animals is worthy of consideration and would be of great advantage.

Ever since the discovery of mallein as a diagnostic agent for glanders, experiments have been conducted by various investigators relative to its immunizing and curative value. Many favorable reports have been made by veterinarians of the results obtained. On the contrary, others appear to have had no satisfaction from its use. Since it has been proved that cases of glanders may recover it is rather difficult to establish the value of the immunizing agents as to their action on the disease. Fortunately, we now possess a means by which the presence of immune bodies can be demonstrated in the animal upon which attempts at immunization are made. With the serological tests at our command we may control to some extent the action of an immunizing substance and observe how long the immune bodies are present in an animal receiving immunization treatment.

It is unfortunate, however, that the demonstration of immune bodies does not indicate the degree of immunity in the animals.

We may obtain in glanders immunization an agglutination value of 1 to 5,000 or over or a complement fixation with 0.02 of a cubic centimeter of serum which may continue for a period of several months, yet this same animal, which apparently is supplied with a great amount of immune bodies, can be readily infected with glanders bacilli. Therefore, in tests undertaken for establishing the degree of immunity against glanders in the horse, it is necessary to expose the injected animals to an infection such as occurs under natural conditions. Observations of such animals as to the clinical appearance of the disease and periodical ophthalmic tests with mallein are the methods by which the most accurate results of the immunization tests can be obtained. Serum tests in these cases are of little value, as they invariably demonstrate immune bodies or antibodies in the immunized animals, and since even small quantities of mallein injected into a horse are sufficient to produce antibodies which remain for 3 or 4 weeks.

PREVIOUS RESULTS WITH VARIOUS IMMUNIZING AGENTS.

Curative results from mallein were reported by Leclainche, Hueppe, Nocard, Johne, and Wladimiroff, while its immunizing value against glanders was studied by Schindelka, McFadyean, and Semmer, but the results were unsatisfactory. Taking into consideration the literature at our command and drawing conclusions from the results obtained, it appears that mallein possesses very little immunizing value and no great benefit can be expected from its use as a curative agent.

Other investigators attempted to immunize horses and other animals against glanders with the use of killed glanders bacilli and the literature contains some favorable results from this method of immunization. The preparations which were employed for this purpose were in most instances suspensions of glanders bacilli killed by heat. Of the various products which have been prepared and are at the present time used to a limited extent for the immunization of glanders, "farase," so termed by Levy, Blumenthal, and Marxer, gives apparently the best results. It is prepared by killing glanders bacilli with 80 per cent glycerin or 10 per cent urea. The bacilli are then dried and the substance is used in that condition for the immunization. It does not contain living bacteria. Favorable results were obtained with farase by Bautz and Machodin, and by Dediulin. The results of Dediulin are probably the most remarkable, since he reports that on an estate where previous to immunization 276 glandered animals had been destroyed, he injected 303 animals and after one year and

four months not a single case of glanders developed, although in the meanwhile 14 cases of glanders developed among 300 nonimmunized animals.

Bautz and Machodin subjected farase to various tests to establish its immunizing value. Their results on guinea pigs, cats, and horses were very satisfactory. Guinea pigs which were given two injections of farase resisted six weeks later an intraperitoneal infection with 1/2500 and 1/5000 mg. of glanders bacilli. Of six horses which received two immunizing injections of farase, two were given 1/2500 mg. of glanders bacilli subcutaneously, two received 1/500 mg. of glanders bacilli per os, and two were exposed with the other animals 45 days after the second injection. For each of the groups one check was used. Post-mortem examination of the check animals four to five weeks after the infection showed typical glanders, while the two immunized animals which received subcutaneous injections of glanders bacilli failed to show any lesions of the disease. No record was obtained of the four remaining immunized animals, as they were turned over to another laboratory for study of the duration of immunity in these horses.

One of the recent works on the immunization of glanders was published by Zurkan, who studied the formation of specific antibodies in the blood of horses under the action of glanders antigens. He concludes that of various antigens such as farase, killed glanders bacilli, mallein, and malleo-aggressin, the first and the last (farase and malleo-aggressin) proved most active in the production of immune bodies. The degree of immunity in the animals was established by Zurkan from the comparative results of the serological reactions he obtained with the complement-fixation, agglutination, precipitation, and opsonic tests. Since there were no practical tests made on these animals, his statement that malleo-aggressin may be used for the immunization of horses against glanders can not be accepted as conclusive.

At the meeting of the American Veterinary Medical Association in Indianapolis, MacKellar presented his conclusions on the protective effect of glanders vaccine. The proportion of infections in the stables where these outbreaks occurred, as indicated by the agglutination test, is astonishing. As there is no mention made in the article of the time the agglutination tests were applied subsequent to the mallein test, it suggests that the large proportion of reactors to the agglutination test were the result of the mallein injection and not due to the presence of the infection. If this be true, then the effect of the vaccine remains indefinite and the control of the disease must be accredited to the other precautions which were observed. At best it will require several years before the value of any method of immunization can be satisfactorily established.

EXPERIMENTS WITH DRIED GLANDERS BACILLI.

The New York City board of health has been conducting immunizing experiments with a vaccine prepared in their laboratory, consisting of a suspension of dried glanders bacilli. Each cubic centimeter of the suspension contains 2 mg. of dried bacilli. Through the courtesy of Dr. William H. Park, director of the laboratory, a sufficient quantity of such vaccine was obtained for conducting a series of investigations relative to the possibility of conferring immunity to animals injected with this vaccine.

GUINEA-PIG EXPERIMENTS.

The experiments were made on guinea pigs and on horses. Twenty guinea pigs, about 600 grams in weight, were divided into 4 groups, 4 pigs of each group receiving three immunizing injections of a definite amount of vaccine at intervals of one week. The size of the doses and other details are presented in Table 1. After the conclusion of these vaccinations one pig from each group was subjected to infection with suspensions of glanders bacilli. These injections with infectious material were administered at various intervals. In all instances the same strain of glanders bacilli was used for the infections. The fifth pig in each group was not vaccinated, but served as a check, receiving only a corresponding quantity of glanders bacilli.

The results of these guinea-pig tests showed that there was not a sufficient increased resistance among the vaccinated guinea pigs to warrant any hopes of successful immunization by this method. It is to be regretted, however, that in the infection of these pigs probably too large a quantity of glanders bacilli was used. On the other hand, it would appear that if there had been any appreciable immunity present in the vaccinated guinea pigs they would have manifested it by a greater resistance against the infection.

TABLE 1.—*Immunization tests on guinea pigs with glanders vaccine.*

Guinea pigs.	Vaccination.			Subcutaneous injection of glanders bacilli.			Bacteriological result.
	Group.	No.	First injection.	Amounts injected subcutaneously at 7-day intervals.		Date.	
				<i>C.</i>	<i>c.</i>	Amount. ¹	Date of death.
1	1	1	May 19, 1913.	0.1	0.3	June 10, 1913	Died June 28, 1913
	2	2	do.	0.1	0.3	June 17, 1913	Died July 14, 1913
	3	3	do.	0.1	0.3	June 24, 1913	Died July 28, 1913
	4	4	do.	0.1	0.3	July 1, 1913	Killed July 20, 1913 ²
	5	5	Check.	0.1	0.3	June 10, 1913	Died July 8, 1913.
2	1	1	May 19, 1913.	0.3	0.5	do.	Died July 12, 1913
	2	2	do.	0.3	0.5	June 17, 1913	Killed July 16, 1913 ²
	3	3	do.	0.3	0.5	June 24, 1913	Killed Aug. 20, 1913 ²
	4	4	do.	0.3	0.5	July 1, 1913	Died Aug. 13, 1913
	5	5	Check.	0.3	0.5	June 17, 1913	Killed June 28, 1913 ²
3	1	1	May 19, 1913.	0.6	0.9	June 10, 1913	Died July 16, 1913
	2	2	do.	0.6	0.9	June 17, 1913	Died July 24, 1913
	3	3	do.	0.6	0.9	June 24, 1913	Killed July 16, 1913 ²
	4	4	do.	0.6	0.9	July 1, 1913	Killed July 26, 1913 ²
	5	5	Check.	0.6	0.9	June 24, 1913	Killed July 5, 1913 ²
4	1	1	May 19, 1913.	1	1.5	June 10, 1913	Died July 5, 1913.
	2	2	do.	1	1.5	June 17, 1913	Died Aug. 2, 1913.
	3	3	do.	1	1.5	June 24, 1913	Killed Aug. 20, 1913 ²
	4	4	do.	1	1.5	July 1, 1913	Died July 8, 1913
	5	5	Check.	1	1.5	do.	Died Aug. 3, 1913.

¹ The amount of injection was 0.5 c. c. of suspension in 10 c. c. or 20 c. c. bouillon containing 1 loopful of surface growth from agar culture.² These guinea pigs were killed on account of extensive suppurating abscesses.

EXPERIMENTS ON HORSES.

In the experiments conducted on horses, 17 animals were used, which were purchased on the open market. Most of the animals were aged, but otherwise in fair condition. All the horses were subjected to the agglutination, complement-fixation, and the ophthalmic mallein tests, prior to the vaccination. All of them proved free from glanders on all the tests. Since the amount of vaccine to be injected for immunizing purposes has not been established, it was deemed advisable to employ varying quantities for the injections, and in order to determine the resistance of the animals against infection during and after the vaccination they were subjected to exposure at different times during the investigation.

The smallest amount of the suspension used for the vaccination was the quantity recommended by the New York City Board of Health, viz, 1, 3, and 5 c. c. per injection, while the largest amount any of the horses received was 4, 8, and 12 c. c., respectively. Two of the vaccinated horses received an infection on the nasal mucosa with glanders bacilli, taken up on the end of a platinum loop, one week after the last vaccination. Both of these horses promptly developed glanders and one of them, No. 102, died of an acute form of the disease 21 days after the infection. Thus, there appeared to be no resistance, or at least no increased resistance, against artificial infection.

To establish the resistance of the vaccinated animals against contact infection a corral was built where all the animals, including two artificially infected glanders cases, were kept. They were fed in common feed boxes and were watered from a common trough. Only one hayrack was used for all animals. Simultaneously with this exposure a stable with three stalls was likewise used for exposing the horses. The construction of the stalls in this stable was such that the animal in the center could reach to the feed boxes of either of the horses in the side stalls. The horse placed in the center was a good discharging case of clinical glanders, whereas the horses placed in the side stalls were either two immunized animals or two controls, all of which were given one week's exposure with this infected horse. This was accomplished by changing the horses in the two side stalls every week, and bringing in two others from the corral, so as to make the exposure as uniform as possible in all animals, including the checks. The conditions of exposure were apparently severe, yet they did not exceed the exposure which occurs in the stables of large cities where the sanitary conditions are very poor and where poor light and ventilation afford a splendid opportunity for the propagation of the disease. In fact, the exposure in the corral was rather slight, since the sunlight no doubt had a destructive influence on the infection.

All animals were subjected periodically to clinical examinations and only four of the vaccinated horses developed signs of the disease up to the conclusion of this experiment, although some of them were exposed since May 16. Horse No. 99, which received 4 immunizing injections and was exposed to a discharging case of glanders in the stable, died 15 days after the exposure from acute broncho-pneumonia malleosa.

In order to determine whether any of the vaccinated horses were infected with the latent form of the disease, all were subjected July 23 to the ophthalmic test. This gave surprising results. Two of the vaccinated animals gave a marked reaction (P + + +). A similar reaction was also obtained in the affected horses used for exposure, while of the two check animals which were not vaccinated but had been exposed to a similar extent as the vaccinated animals, only one responded to the test; the other check animal failed to give any reaction. One month later all horses in the experiment were again subjected to the ophthalmic test. The results were the same as on the previous test, but it was noted that the intensity of the reaction was not as pronounced as in the first test. The inflammation and amount of purulent discharge were somewhat less than in the previous test. This observation coincides with that of Meyer, who states that after several eye tests in positive cases of glanders the degree of the reaction becomes less distinct.

The detailed account of the results of the immunizing tests in horses is given in Table 2.

TABLE 2.—*Immunization tests on horses with glanders vaccine.*

Horse No.	Amount and date of vaccination.							Ophthalmic tests.			Post-mortem.	Remarks.
	1 c.c.	2 c.c.	3 c.c.	4 c.c.	5 c.c.	8 c.c.	12 c.c.	Date of exposure.	July 23, 1913.	Aug. 23, 1913.	Jan. 14, 1914.	
90.....	1913. Mar. 28	1913.	1913. Apr. 4	1913.	1913. Apr. 11	1913. Apr. 25	1913.	May 16				Died May 31, 1913.
107.....	do.	do.	do.	do.	do.	do.	do.	May 16	—	—	P++	Died Apr. 21, 1913.
86.....	do.	do.	do.	do.	do.	do.	do.	Apr. 18 ¹	P+++	P++	P+++	Killed Jan. 16, 1914.
102.....	do.	do.	do.	do.	do.	do.	do.	do.	P+++	P++	P+++	Died May 9, 1913.
111.....	do.	do.	do.	do.	do.	do.	do.	do.	P+++	P++	P+++	First clinical symptoms of glanders Apr. 23, 1913. Killed Jan. 16, 1914.
110.....	do.	do.	do.	do.	do.	Apr. 25	do.	May 16	—	P++	—	Killed Aug. 20, 1913.
105.....	do.	do.	do.	do.	do.	do.	do.	do.	P+++	P++	—	Killed Aug. 20, 1913. No clinical signs.
117.....	May 2	do.	do.	May 9	do.	May 16	do.	do.	—	—	—	Died Oct. 17, 1913. Clinical symptoms.
118.....	do.	do.	do.	do.	do.	do.	do.	May 21	P+++	P++	—	Killed Aug. 20, 1913. No clinical signs.
119.....	do.	do.	do.	do.	do.	do.	do.	May 28	—	—	—	Died Oct. 25, 1913. Clinical symptoms.
120.....	do.	do.	do.	do.	do.	do.	do.	May 21	—	—	—	Killed Aug. 20, 1913.
123.....	do.	do.	do.	May 20	do.	May 27	June 24	June 20	—	—	P+++	Killed Jan. 16, 1914.
124.....	do.	do.	do.	do.	do.	do.	do.	do.	P+	P+	—	Killed Aug. 20, 1913.
94 ²	do.	do.	do.	do.	do.	do.	do.	May 16	P+	P+	—	Killed Aug. 20, 1913. No clinical signs.
121 ²	do.	do.	do.	do.	do.	do.	do.	May 20	P+++	P+++	P+++	Killed Jan. 16, 1914.
82 ³	do.	do.	do.	do.	do.	do.	do.	do.	P+++	P+++	—	First clinical symptoms of glanders Mar. 26, 1913, and continued to progress. Died Oct. 15, 1913.
122 ⁴	do.	do.	do.	do.	do.	do.	do.	do.	P+++	P++	—	First clinical symptoms of glanders May 26, 1913, and continued to progress. Died June 16, 1913, of flatulent colic.

¹ Infected.² Not vaccinated.³ Infected Mar. 21, 1913, and used to expose other horses.⁴ Infected May 22, 1913, and used to expose other horses.

AGGLUTINATION AND COMPLEMENT-FIXATION TESTS.

In order to study the effect of the immunizing injections on the serum tests, the blood of the horses in this experiment was subjected to the agglutination and complement-fixation tests from the time of the first injection until the conclusion of the work. It was found that the agglutination value of the serum of the vaccinated horses as a rule increased from the third day after the first vaccination and continued to rise for a time. A decrease was again noted from two to four weeks after the last vaccination and appeared practically normal after six weeks to two months. A complement fixation with the sera of the vaccinated horses was obtained from the seventh to the ninth day after the first vaccination and they continued to give positive fixations from two to three months after the last vaccination.

These negative serological results which followed the positive reactions due to the injected vaccine, appeared only in the animals which gave no reaction to the ophthalmic test, while the blood of those vaccinated horses which gave a positive reaction to the eye test continued to give a positive fixation until they had been destroyed and proved to be affected with the disease. The same condition was observed in the animals which had been artificially infected with glanders.

The serological results from these investigations appear to have a great significance with reference to the immunity produced by the injection of dead glanders bacilli. The fact that the demonstration of the presence of immune bodies in the vaccinated horses ceased entirely in two or three months from the last vaccination would indicate that after the lapse of such a time the animals have very little or no immunity against the disease. This is further substantiated also by the agglutination value of the sera returning to the normal level. As a matter of fact, previous investigations carried out by Dr. Buck, of this laboratory, showed that one or two subcutaneous injections of mallein will give a complement fixation which may last from one to two months. The agglutination value of the serum of such animals is also markedly influenced by subcutaneous malleinization. The serum reaction of horses following the subcutaneous injections of mallein is given in detail in Table 4. From this it seems that a mallein injection has almost the same action on the production of immune bodies in a horse as killed glanders bacilli. Table 3 indicates the results obtained with the agglutination and complement-fixation tests in the animals used in this investigation.

On August 20 two vaccinated horses and one check animal which gave positive results to the eye test were destroyed, and in all three animals marked pulmonary glanders was observed. Horse No. 105 showed the presence of glanders nodules in the lungs in very great numbers, some of which were of the size of a walnut. In the two other cases, while the nodules were very numerous and from their

appearance appeared to be active, they were of smaller sizes, ranging from a pinhead to the size of a pea. Horses Nos. 110, 120, and 124 were killed on the same day, although they had failed to show any indication of glanders by the eye test, which was also substantiated by the complement-fixation test with the blood of these animals. Post-mortem examination showed no signs of glanders in these animals.

The final results are quite striking relative to the deficiency of immunization against glanders by killed bacteria.

Of the remaining horses which were kept under observation, as indicated in Table 2, Nos. 117 and 119 died on October 17 and 25, respectively, of acute glanders after developing the clinical form of the disease. No. 86 also showed indications of the disease in the early part of October. The final test on the remaining horses, namely, Nos. 86, 111, 121, and 123, was undertaken in the early part of January, 1914, when they were subjected to the ophthalmic and subcutaneous mallein tests and also to the complement-fixation and agglutination tests. All horses reacted to these different tests with the exception of No. 86, which reacted to the fixation, agglutination, and ophthalmic tests but failed to react to the subcutaneous mallein test. Two days following the tests all the animals were destroyed and careful post-mortem examinations were made. The results showed glanders lesions in all animals, including No. 86, in varying degrees. The lungs in all cases contained numerous glanders nodules most of which were in an active stage, and in horse No. 86 the apex of the left lung showed a typical glanderous pneumonia with the characteristic gelatinous infiltration and numerous nodules of various sizes throughout the remainder of the pulmonary tissue.

It is interesting to note that all these vaccinated horses returned to the normal serum reaction of a negative case on or before the twelfth week after the vaccination, as may be seen from Table 4. The exposure in the corral was continued the same as during the entire course of the experiments and the weekly changes of stable exposure were also carried out. The appearance of the disease in these remaining animals seems to offer a more substantial basis for drawing conclusions as to the unsatisfactory results of these vaccination tests.

From our experience with outbreaks of glanders in stables, it appears that these experimental horses did not develop clinical manifestations of the disease in greater proportion than is the case with the average exposed horse. It is true that the exposure of the horses in the experiments was continuous although not unusually or unreasonably severe. Whether the horses which were included in this final test possessed a certain degree of immunity as a result of the vaccination, during the period including the time between the first exposure and the last negative eye test, it is impossible to say; but

TABLE 3.—Serum reactions in horses vaccinated against glanders.

Agglutination.		Complement fixation with 0.1 c.c. and 0.2 c.c. of serum.														
Horse No.	Vaccination period.	During vaccination period.					After vaccination.									
		At first vacci- nation.	Second week.	Fourth week.	Sixth week.	Eighth week.	Twelfth week.	At first vacci- nation.	Second week.	Fourth week.	Thirteenth week.	Sixteenth week.	Eighteenth week.	Twentieth week.	Oct. 14, 1913.	
99	Mar. 28 to Apr. 25.	1:400—	1:2,000+	1:2,000+	1:2,000+	1:2,000+	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	Died May 31 from acute glanders and influenza.
86	do.	1:400—	1:2,000+	1:2,000+	1:1,500	1:1,500	1:1,000	1:1,000	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	Killed Jan. 16, 1914. Post-mortem showed acute glanders.
110	do.	1:400—	1:1,500	1:2,000+	1:2,000+	1:2,000+	1:1,000	1:1,000	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	Noglanders. Killed Aug. 20, 1913.
105	do.	1:400	1:2,000	1:2,000+	1:2,000+	1:2,000+	1:1,500	1:1,500	1:800	1:2,000	1:2,000+	1:400—	1:400—	1:400—	1:400—	Post-mortem showed acute glanders.
117	May 2 to May 16.	1:400—	1:2,000	1:2,000+	1:2,000+	1:2,000+	1:1,000	1:1,000	1:400	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	Post-mortem showed pulmonary glanders.
118	do.	1:400	1:2,000	1:2,000+	1:1,500	1:1,500	1:1,500	1:1,500	1:800	1:1,500	1:2,000	1:400—	1:400—	1:400—	1:400—	Post-mortem showed pulmonary glanders.
119	do.	1:400—	1:1,500	1:2,000+	1:1,500	1:1,500	1:1,000	1:1,000	1:400	1:400—	1:400—	1:400—	1:400—	1:400—	1:400—	Died Oct. 25, 1913. Post-mortem showed acute glanders.
120	do.	1:400	1:2,000	1:2,000+	1:2,000+	1:2,000+	1:1,500	1:1,500	1:800	1:400	1:400	1:400	1:400	1:400	1:400	Post-mortem showed no signs of glanders.
123	May 20 to June 24.	1:400	1:2,000	1:2,000+	1:2,000	1:2,000	1:1,500	1:1,500	1:1,000	1:400	1:400	1:400	1:400	1:400	1:400	Killed Jan. 16, 1914. Post-mortem showed pulmonary glanders.
124	do.	1:400	1:1,500	1:2,000	1:2,000	1:2,000	1:1,500	1:1,500	1:800	1:400	1:400	1:400	1:400	1:400	1:400	Post-mortem showed no signs of glanders.
94	Unvaccinated check infected by exposure.	1:400—	2 1:400	2 1:800	2 1:1,500	2 1:2,000	2 1:1,500	2 1:1,000	2 1:800	2 1:800	2 1:800	2 1:800	2 1:800	2 1:800	2 1:800	Post-mortem showed pulmonary glanders.
121	Unvaccinated check remained healthy.	1:400	2 1:400	1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	2 1:400	Killed Jan. 16, 1914. Post-mortem showed pulmonary glanders.
		1 Before exposure.											2 After exposure.			

a After exposure.

1 Before exposure.

TABLE 4.—*Serum reactions in normal horses following the subcutaneous injection of 1 cubic centimeter of mallein.*

Horse No.	Test	Jan. 31, 3 days.	Feb. 3, 9 days.	Feb. 6, 12 days.	Feb. 9, 15 days.	Feb. 13, 20 days.	Feb. 17, 24 days.	Feb. 20, 27 days.	Feb. 23, 30 days.	Feb. 27, 34 days.	Mar. 3, 37 days.	Mar. 6, 41 days.	Mar. 10, 44 days.	Mar. 13, 47 days.	Mar. 17, 51 days.	Mar. 21, 55 days.
96	Complement fixation	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2
	Agglutination	1:500—	1:800—	1:800—	1:800—	1:800—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—
98	Complement fixation	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
	Agglutination	1:800—	1:2,000	1:1,500	1:1,500	1:2,000	1:2,000	1:1,500	1:2,000	1:1,500	1:1,000	1:1,000	1:1,000	1:1,000	1:800	1:500—
102	Complement fixation	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
	Agglutination	1:600—	1:1,000	1:1,000	1:1,000	1:1,000	1:1,000	1:1,000	1:800	1:800	1:600	1:800	1:600	1:600	1:500—	1:500—
103	Complement fixation	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
	Agglutination	1:500—	1:800	1:1,000	1:1,000	1:800	1:800	1:600	1:500	1:500	1:500	1:500	1:500	1:500	1:500	1:500—
107	Complement fixation	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
	Agglutination	1:800—	1:1,000	1:1,500	1:1,500	1:2,000	1:2,000	1:1,500	1:1,000	1:1,000	1:1,000	1:1,000	1:1,000	1:800	1:800	1:500—

SERUM REACTIONS FOLLOWING A SECOND INJECTION OF 1 CUBIC CENTIMETER OF MALLEIN MAR. 28, 1913.

Horse No.	Test	Mar. 31, 3 days.	Apr. 3, 6 days.	Apr. 7, 10 days.	Apr. 10, 13 days.	Apr. 14, 17 days.	Apr. 17, 20 days.	Apr. 21, 24 days.	Apr. 24, 27 days.	Apr. 28, 31 days.	May 1, 34 days.	May 5, 38 days.	May 8, 41 days.	May 12, 45 days.	May 15, 48 days.	May 19, 52 days.	May 22, 55 days.	June 2, 67 days.
96	Complement fixation	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2	0.1 0.2
	Agglutination	1:500—	1:500—	1:600	1:800	1:500—	1:500—	1:600	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—	1:500—
98	Complement fixation	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
	Agglutination	1:800	1:1,500	1:2,000	1:2,000	1:1,500	1:1,500	1:1,500	1:1,000	1:800	1:600	1:600	1:600	1:600	1:600	1:600	1:500—	1:500—
103	Complement fixation	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
	Agglutination	1:600—	1:1,500	1:2,000	1:2,000	1:2,000	1:2,000	1:1,500	1:1,000	1:1,000	1:800	1:800	1:800	1:800	1:800	1:800	1:500—	1:500—

Quantities of serum employed in complement-fixation tests, 0.1 c. c. and 0.2 c. c. Fractions represent the approximate degree of fixation as compared with complete fixation. SI+ indicates slight fixation.

Six dilutions of sera employed in agglutination test: 1:500, 1:800, 1:1,000, 1:1,500, and 1:2,000.

from the sanitarian's standpoint this would be of theoretical importance only, since even if such should be the case an immunity of from two to four months could not be considered sufficient for practical vaccination purposes. Furthermore, it should be remembered that some of these horses developed a latent form of the disease in less than three months from the last vaccination during the period in which the blood still contained the so-called immune bodies.

CONCLUSIONS.

The results obtained by these investigations appear to be sufficient to demonstrate the unsatisfactory results of this method of immunization. Of the 13 immunized animals, 9 contracted the disease from natural exposure, which is a large proportion when it is considered that all animals were aged and kept most of the time during the exposure out of doors. Of the 4 remaining immunized horses, 1 died of impaction after the second vaccination, while the other 3 animals were killed August 20, 1913, in order to ascertain by post mortem examination the possibility of glanders existing in these animals which had given positive serum reaction, but which had returned to normal. In artificial infections of the vaccinated animals they showed no resistance whatsoever, as both vaccinated horses promptly developed an acute form of the disease from touching the Schneiderian membrane with a platinum loop which had been touched to a growth of glanders bacilli. For the present, therefore, it seems advisable to abstain from immunizing horses by this method, as a practice of this kind may do more harm than good. Owners having horses which are supposedly immunized would naturally become careless, thinking their animals were resistant to the disease, and thus even a better opportunity would be offered for the propagation of the disease than if the horses were not vaccinated. Furthermore, the fact that the blood of vaccinated animals can not be utilized for serum tests for two or three months after the injections is also a great disadvantage in the eradication of the disease.

As a result of this preliminary work it appears that the control and eradication of glanders must still be dependent upon the concentration of our efforts in eliminating infected horses and the adoption of proper precautions against the introduction of infected animals into stables free from the disease. The results achieved in Germany, Austria, and Canada by these methods have proved very encouraging, and no doubt if executed in the same spirit in this country a marked reduction in the cases of glanders would result.

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BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 71



Contribution from Office of Experiment Stations, A. C. True, Director.
April 30, 1914.

(PROFESSIONAL PAPER.)

THE WET LANDS OF SOUTHERN LOUISIANA AND THEIR DRAINAGE.

By CHARLES W. OKEY, *Drainage Engineer.*

INTRODUCTION.

Louisiana ranks second among the States in the area of swamp land within its borders and in the percentage of its total area that is classed as swamp land. Of a total area of 45,420 square miles, 15,930 square miles, or 35 per cent, are classed as swamp and overflowed land. The drainage of these lands is a public improvement of very great importance to the future wealth and prosperity of the State. Although the magnitude of the task has long been recognized and the tremendous advantage that the reclamation of these lands would bring to the State has been admitted by all concerned, it is only recently that the work of putting the swamp land into condition for cultivation has been attempted on any large scale. A number of conditions are responsible for this delay in the work, among which the following are important:

First, a very large proportion of the swamp lands of the State was at one time subject to overflow by the Mississippi River. The first step in the drainage of these lands was to protect them from river overflow by levees constructed along the main river channels. This phase of the work has been going on in some parts of the State for more than 100 years, and in nearly all parts of the overflowed section since about 1875. It has been carried forward as fast as the funds could be secured for the work. Second, the former abundance of cheap and well-drained agricultural land in this and other parts of the country made these lands unattractive. Third, the necessary State laws were not until recently enacted.

As the above-mentioned obstacles are now in a measure removed, the work of swamp-land drainage is attracting serious and widespread attention. The most active field of drainage operations is at present in the southern portion of the State, and it is here that the Office of Experiment Stations, United States Department of Agriculture, has for about four years been carrying on drainage investigations. The purpose of this work has been: (1) To study the soil, climate, and other natural conditions with special reference to the drainage problems encountered and the value of the land for agricultural purposes when successfully drained. (2) To collect such technical data and to examine

NOTE.—This bulletin contains information of value to landowners, engineers, and others interested in drainage by pumping, especially of the wet prairies along the Gulf Coast.

such details of present practice as will afford information of value to landowners, and especially to engineers interested in the reclamation of such lands. (3) To disseminate in available form the results of the investigations and to encourage land drainage by emphasizing the benefits to be derived from bringing such lands under cultivation.

The work in this field was started in 1909 by Prof. W. B. Gregory, of Tulane University, New Orleans, and Mr. A. M. Shaw, then a drainage engineer in the employ of this office. It was continued under their direction until early in 1910, when C. W. Okey, drainage engineer, was placed in charge. Certain lines of investigation have been carried forward continuously since 1909, but it has not been possible to give the work uninterrupted personal attention since 1910. At frequent intervals reports have been made of results obtained, and as often as seemed advisable partial reports have been published.¹

It is the purpose in this bulletin to include all of the salient features of the information so far published and to give also the results of later investigations. Where direct quotations from earlier publications are made, credit will be given, but much of the material contained in the earlier publications and reports will be so interwoven with later and more complete information that no specific mention will be made of its source. The scope of this bulletin is as follows:

First, a description of general conditions in this section of the State, of such a nature and in such detail that persons unfamiliar with this or similar sections of the country will be able to form a fairly accurate idea of the nature of the problems encountered in the successful drainage and cultivation of these swamp lands.

Second, a statement and brief consideration of some of the larger drainage problems encountered, emphasizing the need of more complete cooperation between the various interested parties in the study and solution of such problems.

Third, the results of detailed examinations of a number of drainage districts, reclaimed or in process of reclamation, and a summary of such results.

Fourth, a consideration of the problems involved in land drainage by means of pumps in Louisiana. This discussion might be considered as a continuation of a former bulletin published by this office dealing with pumping in the upper Mississippi River Valley.²

LOCATION AND GENERAL CONDITIONS.

As shown by the accompanying map (fig. 1), the area under consideration lies on the immediate Gulf coast. A range of hills running eastward from Baton Rouge, the State capital, to Lake Pontchartrain, forms with the lake the northern boundary of the portion lying east of the Mississippi River. Most of the land in this area is from 1 to 3 feet above sea level, with a very small percentage lying along the river and the larger bayous having an elevation of from 4 to 15 feet above sea level. To the westward, between the Mississippi and the Atchafalaya Rivers, the land gradually rises from sea level along the Gulf to an elevation of perhaps 15 or 20 feet along a line drawn from Baton Rouge to Lafayette, except that in the immediate vicinity of the Atchafalaya River the land is but very little above sea level. As in the area to the east of the Mississippi River, there is in this section a small percentage of higher land along the rivers and bayous. To the westward of the Atchafalaya River there is a strip of swamp land which borders the coast line and which gradually rises from sea level to approximately 10 or 15 feet above, at a distance of 20 or 30 miles inland.

¹ See especially U. S. Dept. Agr., Office Expt. Stas. Rpt. 1909, p. 415.

² U. S. Dept. Agr., Office Expt. Stas. Bul. 243.





The area of the district is roughly 12,000 square miles, of which amount about 10 per cent is high enough to be drained by gravity, this representing the percentage of the total area that is already drained and under cultivation. The remainder is so low that artificial means must be used to get an outlet for drainage water. The area shown in figure 1 is about one-fourth that of the entire State, yet the tract contains nearly two-thirds of the State's swamp land.

Throughout the entire district are connecting lakes and bayous, many of which are navigable with boats of considerable draft and beam. The total length of such navigable streams is, roughly, 1,600 miles. The main waterway is the Mississippi River. The Atchafalaya River has lately been opened to deep-water navigation through a dredged channel at its mouth, and vessels of a draft of not more than 20 feet can safely enter it. This system of waterways insures excellent water transportation to the entire district, in addition to the facilities afforded by the railroads, a number of which traverse the district.

Besides the cities of New Orleans and Baton Rouge, there are several considerable towns in the district, including Morgan City, with a population of about 5,000; Houma, 5,000; Donaldsonville, 4,000; New Iberia, 7,500; Lafayette, 6,400; and Crowley, 5,000. Lake Charles, the principal railroad center of the western part of the State, has a population of 12,000.

The very small percentage of this area that is under cultivation is worked very intensively and supports a population of over 200 to the square mile. While the principal industry of the whole region is agriculture, the wealth derived from other sources, including sea food, lumber, oil, gas, salt, and sulphur, is almost as great.

CLIMATE.

TEMPERATURE.

The United States Weather Bureau has issued summaries of the climatological data of the United States by sections. Southern Louisiana is designated as section 45, and from the summary for this section¹ the following is taken:

Climatic conditions over southern Louisiana are marine in character; the proximity of the Gulf of Mexico and the numerous streams and lakes of this region all conspire to modify the temperature conditions and prevent sudden changes therein, and extremely warm weather in summer and severe cold in winter seldom occur. Southerly winds from the Gulf temper the climate and prevent, both in winter and summer, extremes that might otherwise occur. The annual mean temperature is 67.9° F. January is the coldest month, with a mean temperature of 52.4°, while July and August are both warm, with mean temperatures of 81.6° and 81.7°, respectively. The highest annual mean temperature is 70.1° at Burrwood, at the mouth of the Mississippi River, and the lowest 66.4° at Cheneyville. The highest monthly mean temperature is 83° at Lawrence in August, and the lowest 49.6° at Cheneyville in January. The range in the annual mean temperature is very slight, and within 100 miles of the coast amounts to only 1°. After passing inland the change is more abrupt, and over the second hundred miles the gradients are steeper than over any other portion of the State, where the fall in the annual mean temperature amounts to 2° in about 100 miles. The stations with the same mean temperature in July and August are situated in the piney woods and the prairie section. The coast marsh and the alluvial region have the highest mean temperature in July. The greatest difference between the July and the August mean temperature amounts to but 0.7°. January averages about 1° to 2° colder than December and February. The range in the mean temperature between the hottest and coldest months is 29.3°.

There is a narrow strip along the coast where the temperature has probably never reached 100°, and even as far north as New Orleans it has not reached this degree except in two years, 1901 and 1909. The highest temperature recorded in the section is 108° at Crenyville, Rapides Parish. The extreme

¹ U. S. Dept. Agr., Weather Bureau Bul. W, sec. 45.

range in maximum temperature amounts to 11°. New Orleans may be taken as a representative station for the southern portion of this section. The maximum temperature has exceeded 100° in but one year, 1901, when 102° was recorded, although a maximum of 100° was recorded in 1909. The temperature reaches 90° every year, but there have been 14 years out of the last 39 in which the temperature did not reach as high as 95°. During 36 years there have been only 78 days when the maximum temperature rose to or above 95° at New Orleans.

The minimum temperatures of this section of Louisiana range from 1° at Amite and Hammond to 19° at Lakeside, the range in minimum temperature being 18°. During 36 years the minimum temperature has been below 32° at New Orleans only 131 days, or an average of less than four times a year. The temperature at New Orleans has fallen below 20° during a period of 36 years in only 4 years, as follows: 1886, 15°; 1895, 16°; 1899, 7°; and in 1905, 18°. Freezing temperatures occur to the Gulf coast in the months of January and February, but owing to the season of the year and the ample warnings given by the bureau to interests affected these frosts seldom cause any loss.

It has been found that the recording stations in the country give somewhat lower mean temperatures and also lower minimum temperatures than stations situated in large cities, as New Orleans. Houma, in Terrebonne Parish, is chosen as representing average conditions in the country in the alluvial sections, and Cameron, in Cameron Parish, as being typical of the coastal plain region in southwest Louisiana. The following frost and temperature data are taken from the records of the Weather Bureau:

Average earliest and latest dates of killing frosts at Cameron, Houma, and New Orleans, La.

Station.	Number of years' record.	Average date first killing frost in autumn.	Average date last killing frost in spring.	Earliest date killing frost in autumn.	Latest date killing frost in spring.
Cameron.....	15	Nov. 26	Feb. 22	Oct. 25	Mar. 20
Houma.....	18	Nov. 20	Feb. 28	do....	Mar. 25
New Orleans.....	37	Dec. 10	Feb. 3	Nov. 11	Mar. 27

Highest, lowest, and monthly and annual mean temperatures, in degrees Fahrenheit, at Cameron, Houma, and New Orleans, La.

HIGHEST TEMPERATURES.

Station.	Number of years' record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Highest.
Cameron.....	16	85	101	89	94	101	101	103	102	104	100	89	87	104
Houma.....	19	81	84	88	92	95	100	102	99	98	93	89	82	102
New Orleans.....	39	82	82	86	89	94	98	102	100	96	94	85	83	102

LOWEST TEMPERATURES.

Station.	Number of years' record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Lowest.
Cameron.....	16	17	13	14	35	39	44	61	45	49	30	20	13	13
Houma.....	19	17	5	25	30	42	51	58	56	44	32	25	10	5
New Orleans.....	39	15	7	30	38	52	58	66	63	55	40	29	20	7

MONTHLY AND ANNUAL MEAN TEMPERATURES.

Station.	Number of years' record.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Cameron.....	14	51.7	53.9	62.6	69.3	75.2	80.7	81.8	81.9	79.0	69.4	61.8	54.9	68.5
Houma.....	18	54.3	55.3	63.4	68.8	75.3	80.3	81.2	81.4	78.5	67.8	61.0	54.1	68.4
New Orleans.....	39	53.9	56.8	63.1	68.7	75.1	80.6	82.3	82.1	78.8	70.3	61.6	55.4	69.1

RAINFALL.

In regard to the yearly rainfall the Weather Bureau summary of the climatological data for section 45 says:

There is a gradual and well-defined decrease in precipitation from the eastern toward the western portion of this section. The average annual precipitation is 55.76 inches, and ranges from 48.36 inches at Lakeside, Cameron Parish, to 63.02 inches at Amite, Tangipahoa Parish. The precipitation is practically all in the form of rain and is well distributed throughout the year. Snow occurs on an average of once in three to five years, and disappears soon after having fallen. Although droughts occur, they are seldom long continued, and are not so serious as in regions where the level of the ground water is so much farther below the surface of the earth. June and July are usually the wettest, and October and November the driest months.

Rain falls about once in three days. The average number of rainy days is 108 in the eastern and from 77 to 80 in the western portion of this section.

The following rainfall data are taken from the Weather Bureau records:

Monthly and annual mean rainfall, in inches, at Cameron, New Orleans, and Houma, La.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Cameron.....	3.67	3.34	3.39	3.61	3.61	5.60	7.57	4.04	5.44	2.88	4.12	3.28	50.55
New Orleans.....	4.54	4.28	4.56	4.53	4.06	5.39	6.53	5.65	4.49	3.25	3.81	4.54	55.63
Houma.....	3.45	4.78	3.52	4.29	3.59	5.98	8.92	6.43	5.92	3.00	2.73	4.31	56.92

The rainfall in this section is more or less tropical in character, especially during the summer months. The rains are nearly always purely local during the summer, and the amount, both daily and monthly, may vary greatly for stations separated by only a few miles. Thus we have a monthly total in August, 1911, of 28.5 inches at Donaldsonville, at the northern edge of this section, and but 12.27 inches at Houma, only about 40 miles away.

The United States Weather Bureau records at the New Orleans station show that there have been 43 storms in the past 22 years, during which the precipitation in 24 hours exceeded 3 inches. These storms are classified as to their intensity as follows:

- 43 rains exceeding 3 inches in 24 hours.
- 19 rains exceeding 4 inches in 24 hours.
- 7 rains exceeding 5 inches in 24 hours.
- 3 rains exceeding 6 inches in 24 hours.
- 2 rains exceeding 7 inches in 24 hours.
- 2 rains exceeding 8 inches in 24 hours.
- 0 rains exceeding 9 inches in 24 hours.

HEALTH CONDITIONS.

As regards the healthfulness of this climate the Bureau of Soils says:¹

A most serious check to the attraction of a desirable class of immigrants to this section is the impression which has gotten abroad as to its unhealthfulness. That this idea had some foundation in the past can not be denied, but such a condemnation can not now be applied to the State as a whole or to this particular vicinity. The records of the medical board of New Orleans show that the city has an excellent health record for a city of its size. * * * Outside of the city sanitary conditions are naturally much better. The dwellings of both the owners and the tenants of the plantations stand on the higher land along the Mississippi River, where there is adequate natural drainage. Not-

¹ U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1903, pp. 443, 444.

withstanding the proximity of the swamps and standing water, malaria, though occasionally occurring, is not dreaded. Until within the last few years epidemics of yellow fever caused frequent alarm, but this disease has now been thoroughly eradicated, and with the methods of treating the disease and preventing its spread it is not to be dreaded as formerly, even if it should again appear.

Since it has been demonstrated that malaria, like yellow fever, can be transmitted to man only through the bite of a certain species of mosquito, it may be expected that drainage, which destroys the breeding places of these pests, will result in a decrease in whatever malaria may now exist. As a matter of fact malarial fever is very rare on the immediate coast line, and the health of people from the North seems to be fully as good as that enjoyed by the natives.

SOILS.

The area under discussion contains soils that are peculiar to the section and these are now for the first time being drained and cultivated. In the following section are set forth the results of first-hand investigations along with the classification and general descriptive matter taken from publications of the United States Bureau of Soils.

AREA EAST OF THE ATCHAFALAYA RIVER.

ORIGIN AND FORMATION OF SOILS.

The soil of the area east of the Atchafalaya River and in parts of St. Mary, Iberia, and St. Martin Parishes is of alluvial origin and is largely the result of deposits made by the Mississippi River and its branches. It has been built up from a depth of several thousand feet to the present elevation above the Gulf. In the very newest portions of the Delta at Port Eads, at the mouth of the river, a considerable subsidence of the land is yet going on, the measured rate being about 0.11 foot per year. That this subsidence is due to a compacting of the newer deposits is shown by the fact that permanent bench marks along the Mississippi River record a decreasing settlement as the distance from the mouth of the river increases. Except in this relatively small area, near the mouth of the river, the remainder of this section of the State shows no change in elevation. As is typical of delta regions, ridges of sandy soil are found along the main river channel and along its branching outlets. The manner in which these ridges were formed is well brought out in the following, from A Preliminary Report upon the Bluff and Mississippi Alluvial Lands of Louisiana, by W. W. Clendenin.¹

With every flood the river now overflows its flood plain and deposits much of the sediment from its headwaters. As with a slight increase in velocity the transporting power is vastly increased, so with a slight checking of velocity, as occurs over the flood plain outside of channel, deposit takes place. As the greatest decrease in velocity takes place near the channel, there the heaviest and coarsest sediment is deposited, and in greatest quantity. The river banks are thus built higher by each flood and a system of natural levees is produced. There is thus a marked difference in the "front lands" and the "back lands" along the river. The former are higher and coarser textured than the latter, and therefore much more easily cultivated and drained.

Drainage from the very channel margin is away from the river, and unless forced by the topography of the land, will not reach the river proper, but unite with some outlet of the river produced during some extraordinary flood period and kept open by the escape of water during ordinary periodic flood stages. As the feeders of the river are called tributaries, these outlets have not inaptly been styled distributaries.

¹ Louisiana Stas. Rpt. Geology and Agriculture, Pt. IV, p. 263.

Since practically all land in the delta region is now protected from overflow by levees along the Mississippi River, and as overflow is now very rare, all building up of the low marshlands has been checked. However, at the mouth of the Mississippi River, deposition of material is continually taking place.

Even before the construction of the artificial levee system, there was no raising of the general level of the marshes during periods of normal flow and probably little sedimentation of the river bed excepting at its mouth, the most of the material which was carried in suspension to the lower portion of the river being carried out and deposited in the Gulf. As the river rose, however, the waters constantly sought additional outlets through the various bayous of the delta country. At times of extreme high water there was a general breaking over the banks of the river and its outlets. It is probable that the most of the building up of the lands above sea level has been done at such times.¹

The above statements show that while the Mississippi River and its various distributaries are continually extending themselves through deposition at their mouths, it was only at times of overflow that the ridges along the channels were raised or widened. The peculiar branched nature of the Delta, with bodies of land extending fingerlike into the Gulf, with open spaces of water between, is also thus accounted for. As these ridges gradually widened they approached each other, thus forming lakes and bayous. Tidal action usually kept these ridges from inclosing the open water between them, and heavy and prevailing winds would no doubt often change their character and direction. It is a noticeable fact that the trend of the majority of the waterways in this section is toward the southeast. As the prevailing winds are from the southeast, and as the usual Gulf currents flow from that direction, most of the sediment was deposited on the western side of the channel. As a result the deeper water always remained to the eastward, and the deposition on the western shore continually forced the channel to the eastward. It is reasonably certain that the large inland lakes, such as Lake Des Allemands and Lake Salvador, were inclosed in this manner.

The fact that the silt-bearing capacity of water is directly dependent upon the velocity is clearly demonstrated by observing the natural embankments formed by streams of various sizes. In the case of smaller streams when the water overflows, its force is soon spent and the silt is quickly deposited near the stream, forming narrow ridges with steep side slopes, while those formed by large streams are broad with slight slopes. Three typical examples, showing this difference and the manner in which the land surface has been raised on the marshes are given in figure 2, A, B, and C.

The sections were taken as follows:

A—From the right bank of the Mississippi River across the Willswood plantation, about 10 miles above New Orleans. This section is about 2 miles long and a part of the lands crossed have been under cultivation for a great many years, while those farthest from the river were reclaimed only 12 or 15 years ago. The lowering of the surface of the cultivated and drained fields due to the shrinkage of humus soils is here well illustrated. There are many examples of highlands having been built up for much greater distances from the river than this, but as such accretions are indirect, on account of being formed by a number of small bayous or temporarily contracted areas of overflow which assisted in maintaining the velocity, these have not been considered as being typical.

B—The right bank of Bayou Lafourche at Lockport, extending back through the village of Lockport and beyond to Lake Fields. Until 1903 Bayou Lafourche served as an overflow outlet for the Mississippi River, the opening at Donaldsonville not having been permanently closed until that year.

C—This is a very small bayou extending to about 4 miles west of Lockport. The abrupt rise of the ridge from the surrounding marshes is especially noticeable and is characteristic of smaller bayous.

¹ Manuscript report of A. M. Shaw.

Important exceptions to the foregoing general statement as to the relation between the size of bayous and the ridges built by them are frequently found.

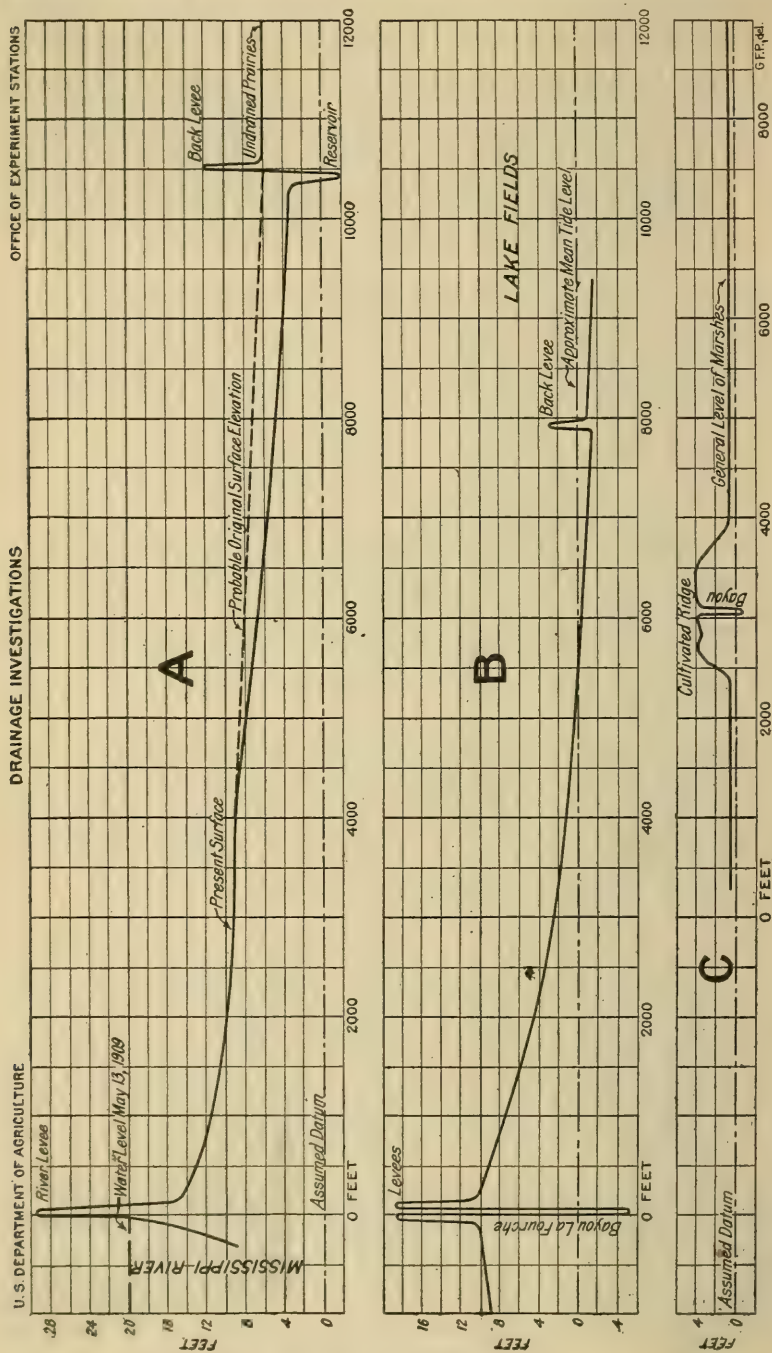


Fig. 2.—Typical examples of Louisiana marshland formation: A, Profile through area No. 1; B, section through area No. 2; C, formation caused by small bayou near Lockport.

Prominent among those are the Bayou L'Ourse, in the southeastern part of Lafourche Parish, and the Wax and Little Wax Bayous, in St. Mary Parish.

Bayou L'Ourse is an insignificant stream, occupying the center of a long and important ridge. It is probable that at one time this bayou served as an outlet for the Lafourche or possibly of some predecessor of the latter bayou, draining in a more easterly direction through Bayou Blue, Lake Fields, and Long Lake. Wax and Little Wax Bayous are streams of erosion rather than of sedimentation and have been formed wholly or in part by the action of storms and the tidal flow which is quite strong along this portion of the coast. As a result, the bayous are bordered by the marsh or by very low ridges. Both streams are from 10 to 50 feet in depth and 100 to 200 feet in width.¹

In addition to the above, Bayous Terrebonne and Black, in Terrebonne Parish, are typical examples of the sedimentation type, while Bayou des Allemands, the connection between Lake Des Allemands and Lake Salvador, is an excellent illustration of the tidal-erosion type.

From the foregoing it may be seen that the chief difference between the various types of soils is the variation in fineness of material, rather than difference in chemical composition.

CLASSIFICATION AND EXTENT OF SOILS.

The various types of soil grade imperceptibly into one another, but the following classifications have been made by the Bureau of Soils of this department: Yazoo sandy loam, Yazoo loam, Yazoo clay, Sharkey clay, muck, and Galveston clay.

The first three classes are ridge soils and are limited in extent, forming a very small percentage of the total area. These soils have sufficient elevation to drain naturally, and as they are practically all well drained and cultivated no discussion of them will be given. For additional information the reader is referred to the publications of the Bureau of Soils.

The last three classes include practically all the undrained soils of this section. The Bureau of Soils says of this first type:²

The Sharkey clay is the heaviest soil of the New Orleans area. It is the most extensive type, and as only a small proportion of it is under cultivation, the subject of the reclamation of the large unused area is attracting considerable attention.

The soil is a heavy black clay to a depth of 5 or 6 inches. The dark color is due to the large content of organic matter which has been derived from the heavy growth of vegetation as the clay was slowly deposited. This decayed vegetation has had a marked beneficial effect on the structure of the soil by causing it to break under the plow into little blocks and to assume a much more favorable condition than is usually possible with this type. The subsoil is a brown or drab waxy clay of a most impervious and tenacious character. The percentage of organic matter is much smaller than that of the soil.

The Sharkey clay shrinks greatly upon drying, and the surface of a drying field is always checked by large sun cracks.

The Sharkey clay occupies the entire land surface of the area, with the exception of narrow strips along the rivers and bayous, where the swifter overflow waters have built up natural levees of coarser sediments, and excepting also considerable areas where it has been covered so completely by decayed vegetation that a muck type has been established. * * * The Sharkey clay areas are for the most part forested. The exceptions are those comparatively small areas in cultivation and the treeless prairies which cover a considerable area in the southern part of the present survey. In the very wet, poorly drained tracts there is an almost impenetrable growth of cypress, willow, maple, water oak, and sometimes ash. On the better drained portions the woods are more open and the palmetto flourishes near the border.

Of the soil classed as muck, the Bureau of Soils says:³

Between the Mississippi River and Lake Pontchartrain are extensive areas where the dense growth of vegetation has decayed and accumulated on the sur-

¹ Manuscript report of A. M. Shaw.

² U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1903, p. 451.

³ U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1903, pp. 452, 453.

face of the Sharkey clay to a depth of from 1 foot to more than 3 feet. This more or less decomposed mass is made up of the trunks and leaves of trees, but more largely of the rank weeds and grasses which flourish in this locality.

The extensive tracts covered by the muck are poorly drained and almost impenetrable. The only places where this type can be seen under any favorable conditions of drainage are between the drainage canals which lead from New Orleans to Lake Pontchartrain. Clearings have been made and it has been demonstrated that the muck can be reclaimed, but so far none of it has been cultivated. The muck in many of the localities in which it was observed is finely divided and well decomposed and should be well adapted to the cultivation of those crops which thrive on the peaty soils.

Of the type called Galveston clay the Bureau of Soils says:¹

The Galveston clay consists of a mucky mass of vegetation in various stages of decay, interspersed with a fine clay of drab color. Along the borders of the marshy prairies covered by this type the soil closely approaches in texture the Sharkey clay, and passes into a subsoil similar to that of the Sharkey clay at lower depths, but the lower lying strips nearer the bayous are little more than peat bogs to a depth of more than 3 feet.

The Galveston clay forms a broad border along the Bayous des Allemands, opening out a short distance above the town of Des Allemands to a width of several miles outside of the present area, with an arm extending northward toward the town of Hahnville. The latter extension follows the course of a sluggish bayou with its many ramifications through the marsh.

The topography of the type is that of a low marsh but little elevated above sea level. Water stands over much of the surface at all times in pools and channels and renders the marsh almost impenetrable except by boat. * * * The areas occupied by this type are entirely treeless and devoid of other vegetation, except sparse marsh grasses which have little value for grazing. This absence of vegetation, in such contrast to the dense swamp growth on the Sharkey clay, is due largely to the brackish nature of the water which ascends the bayous at high tide, and perhaps in part to the peaty nature of the soil, with its poor drainage.

From the foregoing it will be seen that the type called Galveston clay is a combination of the so-called Sharkey clay with muck, with the former as a subsoil. Over the whole of the wet prairie section of the Delta this type of soil is found, the muck varying in thickness from a few inches to several feet. The tracts of land that are now being reclaimed in southern Louisiana all contain more or less of this muck land, and many of the districts are entirely covered by it.

DRAINAGE CHARACTERISTICS OF SOILS.

As the ultimate success of most of the reclamation districts of this section will depend on the successful drainage and cultivation of these muck lands, a rather detailed study of them was made. In investigating these soils it was the endeavor to get a careful description of their physical characteristics, to find the percentage of water by volume that they would contain when in good condition for growing crops, and to ascertain the amount of water they would hold when completely saturated.

The muck is a mass of vegetation in varying stages of decay and contains varying amounts of river silt. In character it differs according to the kind of vegetation from which it was derived; thus the muck of the cypress swamp is much darker and less fibrous than the muck or turf of the open grass-covered prairie. Also, according to stage of decay, it may be tough and fibrous and able to bear the weight of a man, or it may be soft and even semifluid if considerable water be present. Being the result of growth rather than of deposit, it has been formed in layers, the depth of which depends largely on the time involved. When a layer of vegetation is covered with a heavy layer of silt all

¹ U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1903, p. 453.

addition to the former ceases, and if conditions are favorable, a new layer of vegetation is formed on the silt above. Thus we have strata of muck varying in thickness from an inch to several feet, with intermediate strata of silt of depths of from 1 inch to perhaps 2 feet. About half of the waterways that extend through these swamps are streams of tidal erosion, and along these streams the high ridges of river silt are absent and the muck is especially deep. Bayou des Allemands, Wax Bayou, and Little Wax Bayou are streams of this character.

The samples of muck examined were taken at just sufficient depth below the surface to insure the optimum percentage of water—i. e., the amount of moisture considered by local plantation owners to be the best for the growth of general field crops. No samples were taken immediately after a rain nor after a long dry period. At the time of taking the samples a description of each field was made, including depth of water table, length of time the field had been drained and cultivated, time since last rainfall, character of original vegetation, nature of present crop, and other conditions peculiar to the tract in question.

The following tables show the results of tests made during the spring of 1910:

Results of soil tests on area No. 3, Raceland, La.

No. of sample.	Depth of sample.	Number of days since rain.	Weight per cubic foot.			Water in soil by volume.			Depth of water table.
			Normal.	Saturated.	Dry.	Normal.	Saturated.	Gain.	
Turf:	<i>Inches.</i>		<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Inches.</i>
12.....	4-10	7	45.8	61.5	7.0	62.1	87.2	25.1	18
13.....	4-10	7	54.4	.....	8.7	73.1	.....	.....	18
22.....	4-10	10	44.0	.....	9.4	55.4	.....	.....	20
23.....	4-10	10	45.8	62.3	12.4	53.4	79.8	26.4	20
24.....	5-10	10	43.9	.....	10.7	53.1	.....	.....	20
25.....	5-10	10	46.7	60.7	14.0	52.3	74.7	22.4	20
30.....	3- 8	14	41.3	61.5	7.6	53.0	86.2	32.3	20
31.....	3- 8	14	41.3	.....	7.9	53.4	.....	.....	20
32.....	6-10	14	51.2	.....	7.9	69.4	.....	.....	22
33.....	6-10	14	47.3	57.6	7.3	64.0	80.5	16.5	22
Turf with silt:									
10.....	8-12	7	57.9	71.3	21.2	58.7	80.5	21.4	20
11.....	8-12	7	61.4	.....	22.8	61.8	.....	.....	20
14.....	12-16	7	64.0	77.6	29.5	55.2	77.0	21.8	18
15.....	12-16	7	66.0	.....	30.0	57.5	.....	.....	18
16 ¹	3- 7	7	53.7	67.9	14.9	62.0	84.8	22.8	20
17 ¹	3- 7	7	56.2	.....	16.9	62.9	.....	.....	20
26 ¹	3- 8	10	54.8	.....	16.9	60.6	.....	.....	24
27 ¹	3- 8	10	46.7	64.9	8.7	60.8	89.9	29.1	24

¹ Turf and silt after being mixed by two years of cultivation.

The above samples were taken from the soil on area No. 3, which lies about 5 miles from Bayou La Fourche and the same distance from the town of Raceland. This district is a part of the open grass-covered prairie and has been well drained for about three years. Its elevation is perhaps a foot above mean tide level, and the soil probably would be classed as "Galveston clay." The fields from which these samples were taken were in cultivation in 1909 and were planted to corn or sugar cane in the spring of 1910. The original vegetation was a wild prairie grass, locally called "paille fina." It was from this grass that the muck or turf was formed. The soil of the top 4 to 5 inches was quite soft and dry, having been recently cultivated. Just below the depth of cultivation the soil became moist, and when compressed water would drip from it. The muck here was of a dark-brown color and was very light and spongy; after drying it became much darker in color. It seemed to be a mass of partially decayed grass and grass roots, and had very little, if any, silt in its composition. The

depth of the muck on this tract varied from 6 to 18 inches. Below this came a layer of mixed turf and silt about 1 foot in thickness, and from here on down to a great depth occurred pure silt which would be classed as "Sharkey clay." The ground-water level stood a little less than 2 feet below the surface, which is about the average depth of drainage secured on this tract. The first 10 samples in the table were taken from the layer of pure turf, the next four, Nos. 10, 11, 14, and 15, from the layer of mixed silt and vegetation just under the layer of pure turf, and the last four, Nos. 16, 17, 26, and 27, from a field on the same tract that had been cultivated for two years, but had not been cultivated in 1910 when the samples were taken. The condition of these last four samples shows the result of plowing deeply, thus mixing the silt and the pure turf, and gives an idea of the conditions that may be expected after the fields have been cultivated for a time.

The following table gives the results of tests of the muck on area No. 4, which lies a little farther out from Bayou La Fourche than does area No. 3.

Results of soil tests on area No. 4, Raceland, La.

No. of sample.	Depth of sample.	Number of days since rain.	Weight per cubic foot.			Water in soil by volume.			Depth of water table.
			Normal.	Saturated.	Dry.	Normal.	Saturated.	Gain.	
Muck:	<i>Inches.</i>		<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Inches.</i>
28.....	4-9	10	48.9	.....	10.0	62.2	.....	.....	18
29.....	4-9	10	51.2	63.7	10.8	64.7	84.7	20.0	18
34 ¹	3-8	14	59.2	.....	10.0	78.7	.....	.....	12
35 ¹	3-8	14	58.2	63.8	10.2	76.8	85.8	9.0	12

¹ Samples 34 and 35 were undoubtedly too moist for optimum percentage of moisture.

The conditions on area No. 4 were similar to those on area No. 3, except that the land on No. 4 had been well drained only eight months and had not been cultivated. The top of the muck was covered to a depth of about 4 inches with a tough sod full of heavy grass roots, but below this sod these roots tapered out to very fine rootlets. The samples contained pure turf, which was very similar to samples 12 to 33, inclusive, of area No. 3.

The samples recorded in the following table were taken from area No. 2, which lies about 1 mile back from Bayou La Fourche, near Lockport, La.

Results of soil tests on area No. 2, Lockport, La.

No. of sample.	Depth of sample.	Number of days since rain.	Weight per cubic foot.			Water in soil by volume.			Depth of water table.
			Normal.	Saturated.	Dry.	Normal.	Saturated.	Gain.	
Muck:	<i>Inches.</i>		<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Inches.</i>
18.....	10-15	4	54.4	.....	21.9	52.0	.....	.....	22
20.....	8-13	4	52.0	.....	13.4	61.8	.....	.....	22
40.....	7-12	14	52.9	73.0	14.0	62.2	94.4	32.2	26
42.....	8-13	14	52.0	61.5	10.7	66.1	81.3	15.2	22
Silt:									
19.....	3-7	4	112.0	.....	88.6	37.5	.....	.....	24
21.....	2-7	4	80.0	.....	48.3	50.7	.....	.....	24
41.....	2-7	14	74.8	85.6	47.0	44.5	61.8	17.3	26
43.....	3-7	14	111.5	.....	81.9	47.4	.....	.....	26

This tract was a part of the grass-covered prairie which contained a number of scattering groves of small willows. It had been cleared and drained for about five years. Its elevation above mean tide level is about 1 foot. The top soil is a layer of almost pure silt which had been laid down on a layer of muck at a comparatively recent date. The layer of silt varies from 6 to 10 inches and the layer of vegetation is perhaps 12 inches in depth. Below this turf is a deposit of pure silt extending to a great depth. The turf or muck in this tract is perhaps older than that of area No. 3; it seems to have been formed from the same kind of vegetation but it is heavier and much darker than that of the latter district. This is probably due to the weight of the layer of silt which had been deposited on it. The ground had been cultivated in 1910 and the part moved by cultivation was quite hard and dry; however, this cultivation did not reach below the layer of silt, into the muck. The first four samples were taken from the layer of muck, while the next four were taken from the silt overlying the muck. The object of testing both layers of soil was to get an idea of the combined water capacity of the two varieties, for many of the plantations have a mixed soil much like that of area No. 2.

The samples recorded in the following table were taken in Bayou La Fourche sandy loam near Lockport and about one-fourth mile back from the bayou.

Results of soil tests near Lockport, La.

No. of sample.	Depth of sample.	Number of days since rain.	Weight per cubic foot.		Water in soil by volume.	Depth of water table.
			As taken.	Dry.		
Sandy loam:	<i>Inches.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Inches.</i>
36.....	3-8	14	105.9	81.2	39.5	40
37.....	3-8	14	105.4	80.6	39.7	40
38.....	6-11	14	105.9	75.4	48.8	40
39.....	6-11	14	105.4	78.1	43.7	40

The soil in this tract is representative of the average soil conditions in the bayou-front plantations. It is also of much the same nature as the ridges of silt that occur in many of the turf or muck lands. The soil has been cultivated for a great many years and little vegetable matter was present. It had already been cultivated in 1910 when the samples were taken. The ground was quite moist to the touch, but was perhaps a little drier than usual. The soil was much the same to a very great depth. The tests were made for the purpose of comparison with the tests of the muck.

It will be noted by comparing samples 40 and 42, in the summary of results of soil tests in area No. 2, with samples 36 to 39, inclusive, taken near Lockport, that the muck soil seems to be more retentive of moisture than the sandy loam of the bayou ridge. The samples of each class of soil were taken at approximately the same depth and on the same date, yet the muck contained nearly 50 per cent more water than the sandy loam. Later in this same season, which was unusually dry, the crops on the muck soil withstood the effects of the drought better than those on the sandy ridge soil.

In general, the layers of turf or muck of southern Louisiana are quite similar in character to those of other swamp regions of the United States, but having been formed on an alluvial deposit and in many cases mixed with silt, the turf after a few years of cultivation works up into a most excellent soil, which is well balanced in chemical composition. This is proven by the excellent yields of both truck and general field crops on such lands near Lockport and

Raceland. The muck of the cultivated fields has a greater density and a darker color than that where the land is undrained and uncultivated. In its original state the pure turf is a light brown, but as it dries and decays it becomes darker and finally is almost black. When first drained it is very light and spongy and when plowed breaks up into rather large pieces, sometimes as much as a foot square, which are pushed ahead of the plow instead of being turned in a furrow. After the second year of cultivation the muck loses its fibrous nature and resembles old sawdust in texture, although being a little darker in color. As cultivation continues the muck mixes more and more with the underlying silt and a much heavier and more impervious soil results.

As such soils dry out and decay they shrink and settle to a considerable degree. In the tests made the average shrinkage of the muck, due to drying alone, was a little over 60 per cent. In average field conditions the shrinkage would never reach this figure, due to drying alone, for the soil would never become as dry as the samples tested. However, on area No. 1 (fully described in succeeding pages) the lowering of the surface of the land by drying and decay after 10 years of cultivation has amounted to about $2\frac{1}{2}$ feet. Samples of soil, once thoroughly dried, would not resume their former volume even when immersed in water for 12 days, and would absorb only 35 per cent of their former volume of water; while originally, when in average condition for growing crops, they had held about 65 per cent of water by volume.

In the reclaiming of turf lands of this character there is always more or less danger that the muck will burn. On some of the newer plantations trouble has been experienced in burning off the growths of weeds and grass that covered the muck. This burning off can be done with safety only when the muck is still wet from a recent rain. During the spring of 1910, which was the driest in southern Louisiana since Government weather records have been kept in the State, the muck began to burn on area No. 4, near Raceland. This tract had been drained but about eight months. A rain of three-fourths of an inch failed to extinguish the fire. It became necessary to dig a ditch around the fire deep enough to reach to the silt below. This method of checking fire is practicable and efficient if it is adopted soon enough.

The danger of the burning of any considerable area of the reclaimed land is very remote. The system adopted in reclaiming this land—that of dividing it up into comparatively small levee districts—would limit the extent of the fire, and the division of the districts themselves into small areas by the lateral ditches makes it impossible for the whole of any plantation to be in great danger from fire. The danger from extensive burning to the muck of unreclaimed swamp land is not great even when the muck is very dry, for the ridges of river silt which occur at frequent intervals would serve as effectual checks to any great progress of the fire. Even if the muck be burned from a tract of land the underlying silt makes a very excellent although a somewhat heavy and impervious soil.

AREA WEST OF THE ATCHAFALAYA RIVER.

ORIGIN AND FORMATION OF SOILS.

Most of the land to the westward of the Atchafalaya River, except as previously noted, is of different origin and character from that of the area just described.

As most of the land of this section consists of recent coastal plain deposits rather than of Mississippi River alluvium, the surface conditions are somewhat different from those encountered in the eastern or delta section of the State. Instead of a succession of ridges and shallow lakes such as occur in the delta

section we have a coastal plain gradually rising from south to north. Along the immediate coast line there is a more or less unbroken sandy ridge through which the local rivers have cut channels. Immediately in the rear of the ridges are stretches of salt marsh very little above sea level, but which gradually rise to the north so that at a distance of some 5 to 10 miles inland they become fresh-water marsh. The larger streams, such as the Mermentau, the Calcasieu, and the Sabine are still depositing alluvium, and since the coast line was elevated these streams have considerably extended the land adjoining them. As the waters of these outlets are very sluggish and are not heavily loaded with silt they have not built up large ridges along the immediate river banks. The alluvial portion is nearly level and the strips of alluvial land along the channels gradually widen as the streams approach the Gulf. These alluvial strips are still in process of formation and of elevation by deposition, since at each high water the adjoining lands are flooded, the rivers not having been leveed.

CLASSIFICATION AND EXTENT OF SOILS.

As before stated, the Bureau of Soils has not made surveys of this section, but has examined and classified the soils immediately north of it. These various clays, clay loams, silt loams, and sandy loams, are described in detail in publications of that bureau.¹ Toward the Gulf the above-enumerated soils are overlaid with muck and alluvial deposits and thus become subsoils.

The lands of this section might be divided into two main divisions, as indicated in the paragraphs on origin and formation: (1) The general wet prairie land, with a comparatively shallow deposit of silt and muck on the surface; and (2) the strips of alluvial land along the river channels or streams. The first class includes the great bulk of the lands of this section. As noted above, the subsoils of this portion are the solid loams, etc., of the higher land, thus affording a solid foundation which is quite different from the soft yielding alluvial silt of the Mississippi Delta swamps. Overlying this subsoil occurs a shallow deposit of partly alluvial silt caused by local erosion and weathering. On the higher and better drained portions there is little or no muck on the surface, although the silt of the top 6 inches is rich in vegetable matter due to the decay of the grasses that grow on these sections. These portions are covered with water only during the rainy season, and during times of long drought ordinary wagons can be driven over them quite safely. Toward the south, however, the land is water-covered practically all of the time, and a layer of muck has formed from decaying prairie grass. In the essential characteristics this muck is very similar to that of the Mississippi Delta section. It averages from 6 to 18 inches in thickness, although in low depressions and shallow bayous it may be several feet deep. Owing to the absence of any extensively silt-bearing streams the muck of these wide level prairie sections is composed almost entirely of vegetable matter, and its dry weight is less than that of the average muck of the delta section. This, however, should not be an undesirable feature, as most of it is so shallow that the cultivation will soon extend into the silt below. As the coast line is approached, as noted before, the marsh becomes salt, but it is covered with practically the same depth of muck. In various places in this section there are broad zones where the silt deposit between the muck and the underlying subsoil is quite deep, perhaps 3 or 4 feet, and has a chocolate-brown color quite similar to the soil of the Sharkey clay regions. These areas are more numerous in the lower portions of the prairie.

¹ U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1901 and 1903.

Along the larger rivers, especially near their mouths, the alluvial belts of soil are quite wide. In these sections the rivers have laid down alluvium many feet in thickness on the older deposits. The building up of these flood plains has been very slow, and the marsh-grass growth has been continuous; thus we have near the top a muck with a high percentage of silt grading down into a silt with a large percentage of vegetable material at a depth of from 1 to 4 feet. Parts of this alluvial section are quite soft—almost semifluid—although the land immediately along the river channels is sometimes quite firm. The muck in these alluvial sections is quite similar to that of the Mississippi Delta section, except that the silt is well mixed with the muck instead of occurring in alternate layers.

CROPS.

The staple crops grown in this section of the State are sugar cane, rice, corn, forage crops, and truck. In certain parts, especially along the lower portion of the Mississippi and in other districts near the Gulf, large areas are planted in oranges and other citrus fruits. In the eastern or delta portion of the section sugar-cane is the most profitable general field crop, while in the western portion rice is grown almost as exclusively as is sugar-cane in the eastern part. In both sections some corn is grown, but not enough to supply the local demand; as a result, good prices are maintained. Of the adaptability of the type of soil called the Sharkey clay, the Bureau of Soils says:¹

The Sharkey clay was not especially adapted to cane and cotton and was no temptation to producers of these commodities, but the increased interest of late years in the production of rice has given a new value to this soil, and if the problem of drainage can be cheaply and successfully solved, the soil is admirably adapted to the production of this crop. Near New Orleans the reclaimed areas are devoted to the dairy business and to market gardening. The fertility of Sharkey clay is almost inexhaustible, and when well drained it is adapted to any crop which requires a fertile clay soil. The crops most profitably grown near New Orleans are onions, cabbage, eggplant, and tomatoes.

From observations on the various reclaimed districts it would appear that all crops grown on the older lands bordering the river can be successfully grown on the prairie lands, although there are some differences in the methods of cultivation. The lands just recently brought under cultivation are much more fertile than these older lands, and with intelligent farming should not require an application of fertilizer for a long term of years.

NATURAL DRAINAGE CONDITIONS.

The natural surface drainage of this section is away from the Mississippi River and larger bayous of sedimentation, directly into the Gulf by way of bayous of the tidal erosion type. However, numerous canals are being cut through the bayous of the first type from the low-lying swamp or prairie lands, thus aiding in the drainage. Water covers the surface of the undrained lands for the greater part of the year. This water comes from three different sources—direct precipitation, river overflow, and tidal overflow.

OVERFLOW DUE TO DIRECT PRECIPITATION.

The water to be removed from these lands comes mostly from direct precipitation, and it is with reference to the removal of this water that the nature and capacity of natural drainage channels will be discussed. Owing to the

¹ U. S. Dept. Agr., Field Operations of the Bureau of Soils, 1903, p. 452.

slight elevation of the land above sea level all of the streams are very sluggish in character. Their surface slopes are always very slight and are due entirely to the piling up of the water in the interior until sufficient head is created to force the water out to the Gulf. At times of high tide in the Gulf and small precipitation in the interior, the current is often reversed in many of the streams, and salt water then flows many miles inland. However, at such times the water in the channels is so low that the tide rarely causes a stage sufficient to flood any of the adjoining land. (This condition should not be confused with tidal overflow, which will be discussed later.) The fluctuation in water level, due to direct precipitation, in the various bayous and interior lakes is never very great and depends quite as much on the direction of the prevailing winds as on the amount of precipitation. Bayou La Fourche is one of the largest and longest natural drainage channels in this section, extending about 120 miles into the interior. A gauge has been maintained for more than three years at a point about 70 miles inland from the Gulf, and back 1 mile from the bayou on a short canal which connects with the general water level in the swamps. The extreme variation of the water surface observed at this gauge was 3.4 feet. At the time of the lowest gauging the salt water had reached this point, so that it was approximately sea level. This low stage was caused by a combination of the following conditions: A prolonged and record-breaking drought, only 1.12 inches of precipitation having fallen in the preceding two months; warm weather giving high evaporation; and northerly winds followed by southerly winds, which later caused a gradual rise by bringing in the salt water. This low stage was 1.3 feet below mean tide for this point. During the winter of 1911-12 the stage reached its greatest height for the three years beginning June, 1909. It was then 3.4 feet above low tide, which is approximately sea level, and 2.1 feet above mean tide. This high stage was caused by a combination of the following conditions: Heavy and continual precipitation, 9.7 inches having fallen in the preceding 40 days, cold weather and small evaporation, and continued southerly winds.

At points farther inland the fluctuation in water level is proportionately greater. The situation on Bayou La Fourche is mentioned because it is typical of all the long sluggish bayous that carry away the drainage water. Most of the interior watercourses are connected with each other by cross bayous and canals so that they are all somewhat similar in their action. The drainage areas are very poorly defined, and no doubt lap somewhat, as some of the connecting canals and bayous often reverse direction of currents, according to the stages of water in the various parts of the system; for this reason it is practically impossible to measure the run-off from these drainage areas. It is probable that the natural run-off is very low, due to small slopes and the rank vegetation on all the land, only about 10 per cent along the bayous being under cultivation. The bayous of sedimentation are quite free from growth of vegetation, many of them having a considerable boat traffic which tends to keep them cleared out and in good condition as drainage channels. Those of tidal erosion are apt to be overgrown with water hyacinths, but owing to their greater depth these are also quite efficient channels. As shown in figure 1, many parts of this section discharge their drainage water almost directly into the Gulf, or into large interior lakes that undergo very little fluctuation in water surface. Thus these areas are relieved of all drainage water due to direct precipitation without great rise of water in the carrying channels. In the interior portions, such as that contiguous to the upper part of Bayou La Fourche, there are often rises of water level of several feet in the main drain-

age channels. In this flat country a rise of 3 to 4 feet in the main drainage outlet is a very serious matter, and one that demands attention.

In reclaiming land in this section the usual practice is to inclose the district with levees to keep out the surrounding water; the drainage water of the land so inclosed is then pumped over the levee into some natural bayou that leads to the Gulf. If the fluctuation in water level in this outlet bayou is great, not only is a more expensive pumping plant equipment necessary, but the cost of the levees is very greatly increased. As the usual height of the levees is but from 3 to 5 feet above the ground level of the marsh, a rise of 3 to 4 feet in the outlet bayou will often endanger the levees or at least cause a considerable seepage through them. The danger from seepage is especially great because the fluctuation of the water level takes place very slowly. Thus in the vicinity of the tidal gauge in Bayou La Fourche, near Lockport, the water stood, during January, 1912, more than $1\frac{1}{2}$ feet above mean tide. Districts in this vicinity that were exposed to this tide did a large amount of pumping to get relief from seepage water.

Up to the present time little attention has been given to the problem of the disposal of the drainage water after it is pumped over the levees. Some sections never will be compelled to give this matter consideration, owing to their favorable locations on or near the Gulf or some other large body of water. On the other hand, there are sections of wet prairie that are isolated from any large bodies of water by distances of from 20 to 75 miles along the shortest natural outlet channel. Thus far few of these districts have experienced any difficulty in getting outlets, for the surrounding limitless prairie is so little above sea level that the drainage water can immediately spread out, and thus causes no trouble. The percentage of land yet reclaimed is so very small that no effect on the carrying capacity of watercourses could yet be expected.

As the work of reclamation goes forward and district after district is reclaimed, until a considerable portion of the whole area is appropriated, the drainage water when pumped over the levees can not spread over the surrounding prairie, for the latter will be inclosed by the levees of adjoining districts. The water will then be forced to flow through long winding channels to the Gulf, this distance often being as great as 75 miles. This will mean that the water level on the outside of these interior districts must rise until sufficient head is created to cause a movement of the water to the Gulf, thus greatly increasing the cost of reclamation and rendering unsatisfactory much of the work that is now apparently finished.

In the planning of gravity drainage districts the common interests of adjacent districts in securing good outlet facilities have in all parts of the country long been recognized. Experience has shown cooperation between such districts to be necessary. As yet, most of the reclamation districts that secure drainage by pumping are independent of each other, and, as pointed out above, those which are fortunately situated will remain so. On the other hand, interior sections will eventually need better outlet facilities to the Gulf if the present policy of developing small independent districts is continued.

It is evident that the various districts should be so correlated that there will be no interference between the different interests. This makes necessary a general survey of this district, covering the topographic and hydrographic features. A survey of this scope would show the probable future necessity of increasing the present capacity of the natural drainage channels, or perhaps of providing additional outlet channels for some of the more isolated sections. It is quite likely that such additional channels could be used as commercial canals, thus making them doubly valuable. The section of the country lying between Bayous La Fourche and Terrebonne, in the parishes of the same names, is an



excellent illustration of an area that eventually will need better outlet facilities, parts of this area discharging drainage water through 80 miles of natural drainage channel to reach the Gulf. As shown by the gauge at Lockport, the natural water surface in the swamps already has a large fluctuation, and any further extensive reclamation of land without improvement of the main drainage channels will doubtless considerably increase this fluctuation. A survey of this area would be needed to determine whether or not the present channel should be improved or whether any channels should be cut through the central portion of the district. Local landholders have suggested the possibility of combining such a main drainage outlet with a commercial canal to the Gulf, thus affording the district better transportation facilities. A thorough survey of the district would determine the feasibility of such a combination of interests.

RIVER OVERFLOW.

Like all delta regions this one was originally subject to periodic overflow. The smaller floods of the Mississippi River were confined within the natural levees that the stream itself has built up, but at irregular intervals of some years great floods would for months cover practically all of the delta. As soon as any serious attempt was made to bring this land under cultivation, levees were built along the Mississippi River banks to protect the lands from overflow. Districts were finally organized which included long stretches of river, and in all millions of dollars have been spent in levee improvements. This expenditure, with such Federal aid as has been available, has built a continuous levee system on both banks of the river throughout its length in the district under consideration. The levees have been increased in size as fast as the protected land could supply the money. In the earlier years, owing to insufficient cross section of levees and low grade line, crevasses were of frequent occurrence in times of high water. As more and more work was done on the levees a greater degree of protection was secured, until now crevasses and consequent overflow are very rare and occur only at times of record-breaking floods. The levee system is still far from complete. As illustrative of the flooding possibilities due to crevasses in the present system of levees, figure 3, published by courtesy of the Mississippi River Commission, shows the area overflowed during the record-breaking flood of 1912. It is evident that not only the reclamation of the swamp land but the successful cultivation of practically all of the higher land east of the Atchafalaya River is dependent upon the prevention of overflow of the Mississippi River. The interests involved in such overflow and the damage resulting are of such ever-increasing magnitude that there is every reason to believe that the work of completing these levees will be done in the immediate future. Prominent levee engineers who are acquainted with the problem believe that with the completion of the levee system this whole area will be protected from overflow of the Mississippi River. The above remarks apply to the alluvial section of the country, as very little land west of the Atchafalaya River is affected by Mississippi overflow. Some of the larger streams, such as the Calcasieu and the Sabine, flood the alluvial flats of land immediately along their banks to a depth of perhaps 4 feet, but as a whole the wet prairie lands of this western portion of the coast are free from river overflow.

TIDAL OVERFLOW.

The daily range of tide along this portion of the Gulf coast is quite small, the average being from 0.5 to 1.5 foot. However, as is true of all low, flat coasts bordering on wide areas of comparatively shallow water, heavy winds which

blow for any considerable length of time directly on shore may cause a rise of several feet in the water. Such rises are commonly called storm tides. Their effect is so great that often they reverse the ordinary tide, and the maximum height of water may be reached at the usual time of low tide. Storms of this character usually occur during the months of August, September, and October, and are known as tropical hurricanes. Those that are severe enough to cause large rises in the tide occur at comparatively long and irregular intervals. Sometimes they will affect only a comparatively small portion of the coast line, while at other times a general rise of several feet will be recorded all along the coast line, with a limited region where the storm center strikes the coast experiencing a tide of perhaps twice the height of the general rise. One of the most characteristic as well as one of the most severe storms ever experienced in this section occurred September 20, 1909.¹ It produced high tides all along the coast and gave the maximum tide at the mouth of Bayou Terrebonne, about 40 miles west of New Orleans.

As it was apparent that this storm was very general in character and caused high tides all along the coast, Mr. A. M. Shaw, who at that time was carrying on investigations in this section for the Department of Agriculture, made special efforts to ascertain the maximum height reached by the tide, and for this purpose visited points all along the coast. The height of the tide was ascertained by the combined testimony of all reliable parties who were on the ground and by high-water marks on buildings. Only information from reliable sources was accepted. To quote from Mr. Shaw's report:

The high-water marks obtained were fairly consistent, and were quite generally above any authentic high-water mark in the same locality.

Figure 1, page 2, shows the section under discussion, with the maximum heights of water above mean tide. With few exceptions this was the highest tide ever experienced on the coast, although more violent storms of limited extent have been recorded. Commenting on these high-water marks Mr. Shaw says:

These may be considered authentic, excepting that the heavy seas that swept over the site of the camp at Sea Breeze made it impossible to get an accurate record at this point. The record shown of 15 feet may be in error 2 or 3 feet.

In regard to the extreme height at this point, he further says:

An examination of the accompanying map will show that the mouth of Bayou Terrebonne lies between two large bays, and it is possible that this unusual rise may be accounted for, at least in part, by the sudden veering of the wind, thus concentrating the extreme tides of both bays on the central point. The foregoing report of the progress of the storm at New Orleans shows that such a sudden change in the direction of the wind did occur at that point and a similar decided change was described by a number of persons on both Bayous Terrebonne and La Fourche, all of the accounts agreeing that this change took place while the storm was at its worst.

An examination of the conditions at this point on the coast shows further reason for this extreme height of tide. The water in both Timbalier and Terrebonne Bays is comparatively shallow, ranging in depth from 4 to 12 feet. It has been the observation of the United States Coast and Geodetic Survey that where the water is shallow for a great distance offshore, heavy winds cause a flow of the entire depth of water, thus allowing no undertow. This action would give the water a tendency to pile up wherever it encountered an obstacle. This explanation is further supported by the fact that on more exposed portions of the coast, but where the water was deeper, the tide was not nearly so high.

¹ For a minute description of this storm at New Orleans, see U. S. Dept. Agr., Monthly Weather Review, 1909, p. 623.

Thus on Timbalier Island, directly opposite the mouth of Terrebonne Bayou, the rise, according to the lighthouse keeper, was only 6 feet. At Port Eads, which is practically 12 miles out in the Gulf, and where the water is much deeper, the rise was only 3.4 feet and subsided in a few hours.

To the westward of this portion of the coast line the tides due to this storm were not nearly so high. This was doubtless due to the difference in the character of the coast line, and to a less intensity and duration of the storm. Concerning this section Mr. Shaw says:

In the western portion of Terrebonne Parish, the flood height amounted to about 5 feet with a gradual falling off to the west. On the Big Wax and Little Wax Bayous and Bayou Sale, in St. Mary Parish, the maximum floods probably do not exceed 4 feet.

As mentioned in the general description of this section, the coast line of the western portion is very regular in outline, and immediately along the beach there is an almost continuous ridge of sandy material. The water directly offshore is deeper than that along the eastern coast, at least is deeper than the numerous lakes and bays of the eastern section, and as a result the tides due to wind have never reached the height experienced along the coast of the eastern part. The high tides have never overtopped these ridges, and as the water only poured in through the low places it did not enter in sufficient volume to flood the land deeply before the recession of the tide occurred. By closing these comparatively short gaps in this ridge, complete protection from tidal overflow would be secured for the western section, but some provision would necessarily have to be made for discharging the natural drainage water from the interior.

From an examination of figure 1 it would appear that reclamation districts on many portions of the coast will be compelled to build levees not only to keep out the water of the surrounding swamps, but also to prevent tidal overflow in times of storm. The heights of the tide indicated on this map are the highest that have been experienced since the country has been settled, and should govern the height of levees on districts in the various localities. From a study of the nature of these tropical hurricanes the Weather Bureau forecaster at this point has concluded that there is an area of maximum velocity of wind in these storms that strike the coast, and that at or near where this maximum velocity occurs a much higher tide than the average may be expected. In the storm of September 20, 1909, the area of highest wind velocity struck the coast at or near the mouth of Bayou Terrebonne. As the storm center may strike at any point in future storms we may expect tides over limited areas exceeding those of the above-described storm, but it is unlikely that in general the present records will soon be exceeded. It is probable that these severe storm centers will occur on the Gulf coast with about the same frequency as do the tornadoes of the upper Mississippi Valley, and therefore it is suggested that protection from them should be sought in insurance rather than in building levees of sufficient height to prevent overflow from these limited areas of extremely high tide.

In connection with the problem of protection from tidal overflow, the plan of providing a general protection levee for the whole of the coast line, rather than of constructing individual levees for each district, has been considered by local engineers. The feasibility and cost of such a plan could be determined only after a complete survey of the district had been made, and a comprehensive plan had been carefully worked out. However, there are some general features that can be stated, thus giving an idea of the nature of the problem. The larger the levee district, other things being equal, the less the cost per acre for levee, for the length of levee per unit of area varies as 1 divided by the square

root of the area. Thus, if the cost for levees on a given district is \$10 per acre, the charge on an area four times larger and of the same shape would be \$5 per acre. Moreover, the doing of work along broad lines and the handling of earth work in large quantities would reduce somewhat the unit costs of construction. A levee location along the coast would have the advantage of a more or less continuous chain of islands, some of which are never overtopped by high tides, and many of which are nearly high enough at present to prevent overflow. That such a levee would not need to be as high, in order to keep out all tides, as one farther inland is proven by the high-water records of the storm of 1909, and those of earlier storms; this fact is also shown by the action of the natural levee along the coast of Vermillion and Calcasieu Parishes. By inclosing large natural depressions, such as bays and salt-water lakes, a considerable reservoir capacity could be secured by regulating the stage of water in them through the use of gates and locks in the levee. This would form basins into which the main drainage channels of the interior could discharge. A levee in such an exposed location must necessarily be capable of resisting the direct action of the waves, and steps would have to be taken to check the present cutting away by the Gulf currents of these natural levees. The oyster and fish industry of this portion of the coast would be greatly affected, as practically all of the oyster beds would be inclosed by such levees. However, if the proportion of salt water could be so regulated as to insure safety to the oyster beds the plan would be of benefit to the industry, as it would protect them from the damaging action of storms. The inclosing of such bodies of open water as Timbalier or Terrebonne Bays would not entirely eliminate storm tides in them; Lakes Ponchartrain and Maurepas, although well inclosed by the natural land surface, showed strong tidal action during the storm of 1909.

DESCRIPTION OF RECLAMATION DISTRICTS.

Previous to about 1907 there had been no active movement in the drainage of the wet prairie lands of Louisiana. The older plantations had extended their clearings back to the belt of cypress swamp that usually lies between the ridge along the Mississippi River and the grass-covered prairie; there, owing to the expense of clearing such land, further progress was usually checked. At some points, however, where this belt of timber was narrow, the plantations have been extended to include relatively small areas of prairie land. Such areas were inclosed with levees, ditches were cut, and pumping plants installed. The land thus reclaimed on such a small scale has proved to be very fertile and has been farmed with entire success. About 5 years ago the present movement for reclaiming large areas of wet prairie land began, and districts consisting entirely of wet prairie land were inclosed by levees and drainage systems installed. The degree of success attending these early reclamations interested people from many points outside as well as within the State, and at present the work is being prosecuted with an ever-increasing vigor. From the drainage engineer's standpoint the work has passed the experimental stage, and by following the best methods used on existing districts the successful drainage of the average type of wet prairie land seems assured. However, owing to the comparative newness of the work, many problems have yet to be satisfactorily worked out.

The degree of success attained in the various methods used in the reclamation of these lands has been quite closely investigated by this office. This investigation has included studies of the natural features of a number of drainage districts and of the levees, reservoir canals, field laterals, pumping plants, and methods of cultivation, as well as the records of rainfall and run-off. A large number of districts have been examined closely, and practically every district within the State has been inspected.

In order better to explain the nature of the drainage problems encountered and the reclamation methods employed, a detailed discussion of a number of reclaimed areas will be given, and a summary of the results of all investigations presented. The areas discussed are arbitrarily designated by numbers. These examinations were made or completed during the spring of 1912, and the descriptions refer to conditions at that time.

EXPLANATION OF TERMS.

Before proceeding with the discussion of the reclamation districts a brief explanation of some of the technical terms hereinafter used will be given.

By run-off is meant the water that flows over or through the ground to drainage outlets. All run-off originates in precipitation; therefore the latter is the most important of all the factors that influence the rate of run-off, some other controlling features being size, shape, topography, and geological structure of the watershed, climatic conditions, and the character of the vegetation.

In so-called gravity drainage districts the run-off is removed by gravity through the main outlets. In pumping districts the run-off is collected at some central point within the district and pumped over or through the levee. The rate of run-off is expressed as a quantity of water removed in a unit of time. This quantity of water can be conceived as a certain depth distributed uniformly over the entire drainage area. Similarly, the capacity of a pumping plant is the quantity of water, expressed in a depth uniformly distributed over the drainage area, that the pump can dispose of in a given time. As used in the following discussion, the rate of run-off is expressed by the depth of water, in inches, distributed uniformly over the drainage area, that passes from the area in a period of 24 hours. Likewise, pumping plant capacity is expressed in terms of a depth of water, uniformly distributed over the drainage area, that can be removed by the plant in 24 hours of continuous operation. Reservoir capacity also is represented by a uniform depth distributed over the drainage area. The object of expressing the rate of run-off and the pump and reservoir capacities in depths rather than in volumes per unit of time is to arrive at a basis of comparison that is independent of the drainage areas. On any particular tract, the area being known, these rates can of course easily be reduced to cubic feet per second or to any other convenient unit.

In a long period the total amount pumped would approximately equal the run-off for that period, but for short intervals, as, say, 24 hours, the run-off from an area might be much greater than the quantity pumped, the excess being stored in the reservoir for subsequent pumping.

AREA NO. 1, WAGGAMAN, JEFFERSON PARISH, LA.

As shown in figure 4, this plantation, containing 2,600 acres, fronts on the Mississippi River and extends back into the prairie swamp lands in the rear. It is a typical example of one of the old river-front plantations which have been extended to include a comparatively large area of wet prairie land. The tract of swamp land, which makes up one-third of the present area of the plantation, was included by the extension of the levees about 12 years ago. A pumping plant was installed, and cultivation has been continuous since that date. The area of prairie included was quite typical of those in this part of the State, and was covered with a scattering growth of small willows and the usual rank growth of prairie grass. Originally the muck was about 3 feet deep, although at present, after 12 years of cultivation and decay, it is well compacted and has subsided or shrunk until it now averages $2\frac{1}{2}$ feet lower than it originally was. The total fall in the surface of the ground from the front

to the rear of the plantation is about 10 feet. Part of the land could doubtless be drained by gravity, but at present all of the water goes to the pumping plant. In February, 1911, 200 acres of land lying along the river front were added to this plantation.

LEVEES.

As part of this tract is above all possible high water due to direct precipitation or tidal overflow, it is only partially inclosed by levees. Starting where the ground is only about 5 feet above mean tide, a levee was built around the lower part to a height of nearly 7 feet above mean tide. The levees were built

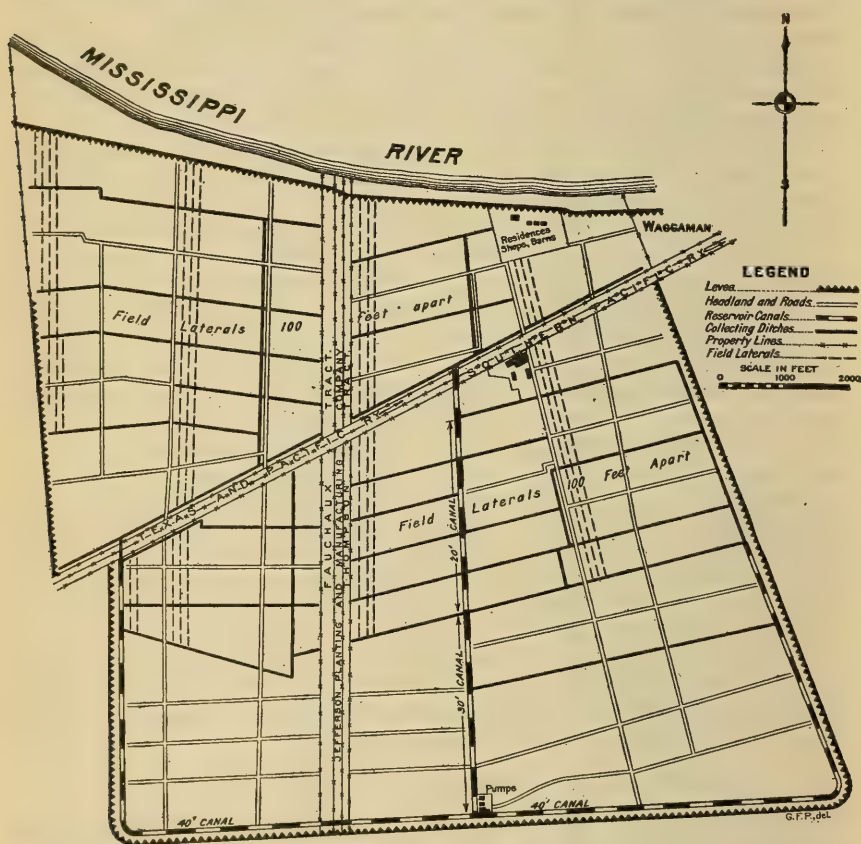


FIG. 4.—Sketch map of area No. 1, Waggaman, Jefferson Parish, La., showing ditch and levee system.

with a dipper dredge with material taken from the inside of the district. The canal resulting from the levee building was used for a reservoir. The ground was very soft and the levees were built up in several layers, but owing to the softness of the ground the excavated material formed a good bond with the foundation. The berm between the levee and the canal is now from 10 feet to 15 feet wide and is quite uniform. As they stand to-day, the levees seem to be almost impervious to seepage water. Nothing could be learned as to seepage during the first few years after construction, and they show no evidence of any sliding of material due to seepage. The levees have a top width of about 5 feet

and side slopes of $1\frac{1}{2}$ to 1. The unusual height is accounted for by the fact that at the time of construction danger from high water, due to breaks in the Mississippi levees, was still great.

RESERVOIR CANALS.

As indicated in the description of the levees, the reservoir canals on this district were cut with a dipper dredge. By using the canal so excavated as a reservoir, it was necessary to construct only a comparatively short canal into the interior of the district in order to give outlet to the collecting ditches. These ditches are mostly about 5 feet deep, with 10-foot top widths and 3-foot bottoms, and serve as outlets to the small lateral ditches.

Owing to an extensive silting up of the reservoir canals, their capacity is very much less than it originally was. During the whole time since their construction no attempt has been made to remove this deposit of silt. As a result the canals are not deep enough to afford outlet facilities to the ditches in the back lands. The pumping operations are also interfered with, in that the water is not brought to the pump rapidly enough to insure continuous operation at full capacity of plant during the removal of the run-off of a rain. This lack of reservoir capacity also makes the operation of the plant very unsatisfactory, as the water level must be kept nearly at the bottom of the canals to afford sufficient depth of drainage to the land. During the coming year it may be that the reservoirs will be cleared of silt with a dredge. This will allow opportunity to see what effect increased reservoir capacity will have on the pumping operations. Doubtless the greatest effect will be to decrease the number of days on which it will be necessary to operate the plant, although it is not likely that the total hours of operation or the amount pumped will be greatly affected.

DITCHES.

The ditches on this plantation are of about the usual cross section, having depths of 3 feet, top widths of 3 feet, and bottom widths of $1\frac{1}{2}$ feet. The average spacing varies with the character of the land. Thus, on the front lands which are rather impervious the spacing is about 100 feet, while on the back portion the ditches are from 300 to 500 feet apart. On the front lands the lengths of the laterals, between collecting ditches, are quite small considering the large slope of the surface of the land. Conditions on similar plantations where the ditches are twice as long indicate that the laterals of this district could safely have been made nearly twice as long as they are.

On the back lands, however, the ditches are already about as long as it would be advisable to have them, since the land is almost level and the reservoir canal quite shallow. At present these ditches are too shallow to give adequate drainage. Some measurements of the depth of water table were made during the early part of the summer of 1910. The results of these measurements are shown graphically in figure 5. It is apparent that as yet this soil is not very impervious, when compared to the lands of the vicinity of Bayou La Fourche and as shown by other similar measurements on area No. 2. (Figs. 8 and 8a, pp. 31 and 32.) Even after heavy rains the profile of ground water is not excessively steep. The ditches are spaced too far apart for the best results, although if they were of full depth they would very nearly drain the ground. It is the intention of the owners of this tract to deepen the present ditches to the usual depth of 3 feet and to construct new ditches midway between the present ones. The situation appears to be favorable to the placing of lines of tile instead of the new set of ditches. As the surface water is already handled by the present

serious matter. The heaviest rainfall that this plant has been called upon to handle since the records were begun occurred in the latter part of April, 1911, when 6.25 inches of rain fell in two days. The plant did not run at full capacity all of the time, so some flooding occurred for about 48 hours in the rear portion of the plantation; no large damage resulted from it, however. In view of the fact that this plant can not be depended upon always to run at full capacity, its present capacity is just about sufficient. There are a number of factors which make the run-off from this plantation greater in amount and intensity than it is from the average district of newly reclaimed wet prairie land. Among these are, first, a fall in the surface from front to rear of the tract of about 10 feet; second, a heavy and impervious soil on all the front lands, which comprise about half the entire area; third, a very complete system of ditches; fourth, complete and intensive cultivation; and fifth, a well-decayed and comparatively impervious prairie land in the rear portion of the tract. However, after the average district has been as long reclaimed as this district has been about the only one of the above factors that will differ, when it comes to making comparisons, will be the surface slope. It seems reasonable to suppose that the percentage of run-off on newly reclaimed districts will gradually increase until it is almost as large as it is on the tract under discussion.

The cost of operation of this plant in labor and fuel has been carefully kept, but due to inefficient machinery and large run-off from the front lands, it is considerably higher than where conditions are more nearly typical. Following is a summary of the cost of operation of the pumping plant on area No. 1 from June, 1909, to December, 1911, inclusive.

Cost of operating pumping plant on area No. 1, June, 1909, to December, 1911, inclusive.

Date.	Rainfall.	Run-off.	Cost.					
			Labor.	Fuel.	Total.	Per acre.	Per inch of water removed over tract.	Per acre-foot lifted 1 foot. ¹
	<i>Inches.</i>	<i>Inches.</i>						
1909 ²	42.32	16.33	\$600	\$936	\$1,536	\$0.64	\$94.00	\$0.09
1910.....	43.08	11.58	500	616	1,196	.50	103.00	.10
1911.....	52.32	23.42	753	1,267	2,020	.77	101.00	.08

¹ Calculated on basis of 5 feet effective lift. Actual lift 10 feet.

² June to December only.

CONDITION OF LAND FOR CULTIVATION.

For two years after this tract of land was reclaimed it was cultivated with only such drainage as was afforded by the reservoir canals. At the end of this time lateral ditches were cut at a spacing of about 400 feet, and good drainage thus secured for a number of years. Not much detailed information was available concerning conditions during this early period. It is known, however, that during this time excellent crops were grown on this prairie land, and that they were uniformly better than those grown on the front lands. Up until the last two or three years the prairie lands were so much better drained than the front lands that plowing could be done on them when the water stood on the surface of the latter. As is shown by figure 5, the depth of drainage is now very small on these lands, hardly more than a foot. However, crops were reported as being

good, even with such shallow drainage. The manager said in this connection that although the crops were good the cane, especially, did not seem to stand drought very well. This probably was due to the very shallow depth of root growth that such a small depth of drainage would permit. As this tract is a part of the typical wet prairie found in this section, the results attained would seem to show that the successful reclamation of these lands already is a certainty.

AREA NO. 2, LOCKPORT, LA FOURCHE PARISH, LA.

This tract (fig. 6) adjoins the village of Lockport and contains 647 acres. The land from which this district was reclaimed is typical of the open grass-

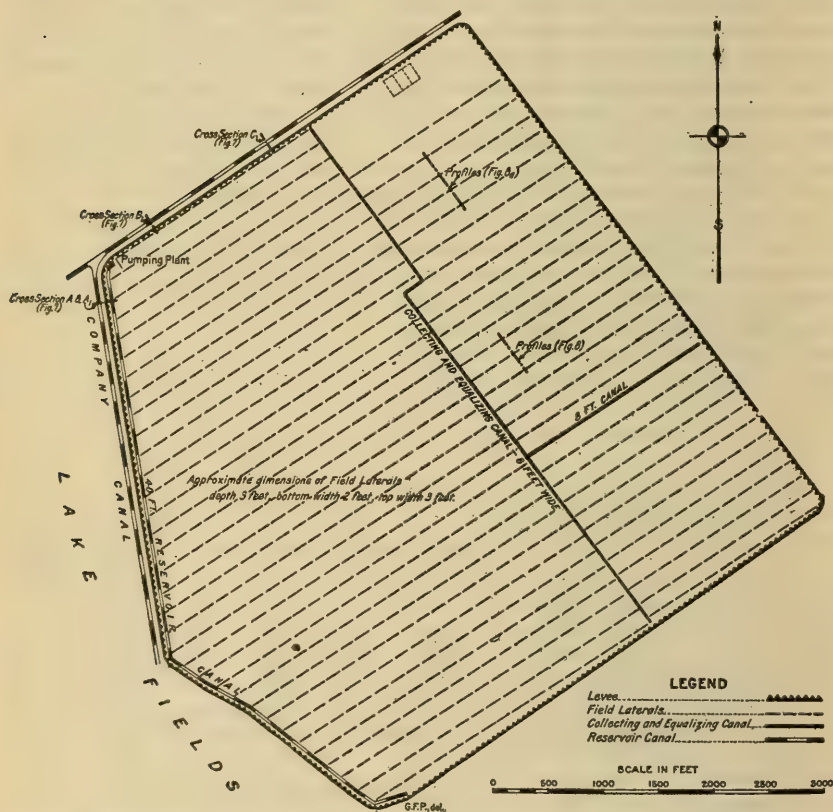


FIG. 6.—Sketch map of area No. 2, Lockport, La Fourche Parish, La., showing arrangement of ditches and levees.

covered prairies that lie to the west of Bayou La Fourche. The front levee line is located about 1 mile back from the bayou, and is nearly parallel to it. From here the tract extends back into Lake Fields, which at one time covered to a depth of from 1 to 3 feet about one-half of the area inclosed with levees. The muck on this tract varies in depth from 18 inches on the higher portions to perhaps 8 inches on the bed of the lake. A detailed description of the character of this muck has been given in connection with the special investigation of muck soils (p. 13). Reclamation on this tract was started in 1907, and the area was nearly all brought under cultivation by the growing season of 1911,

LEVEES.

The front or northeast levee on this tract is located on ground about 2 feet above average tide. As the storm tide in this place is only about 2.5 feet above mean tide, the front levee is very small, perhaps 2 feet high and having a bottom width of 5 feet. Along the outside of this levee is a small diversion ditch designed to carry the water draining from the higher land in front across to the commercial canal on the side of the tract. Owing to the small size of the levee and also to the fact that it was built by hand, considerable seepage water finds its way into the front part of the district. The trouble from this source is noticeable only when the tide stands about a foot above mean height for any great length of time. Along the other three sides of the tract it was necessary to construct a levee varying in height from 3 feet at the front to 6 feet at the back along Lake Fields. Along this portion the present crown of the levee is about 5 feet wide, with a bottom width of about 35 feet. This would give a side slope of about $2\frac{1}{2}$ to 1.

The levee along the north and south sides not only is in good condition, but it seems to allow about the minimum amount of seepage during ordinary stages of outside water, although there is no berm between the levee and the outside canal. There is no lateral ditch on the inside¹ of the levee nearer than about 180 feet, so that the actual difference of the water levels inside and outside of the district is rarely greater than 4 feet, and usually about 3 feet. While the percentage of muck in this levee is small, there seems to be a rather continuous layer of muck in the base. At ordinary stages of water there is no great seepage through this layer of material, but during December, 1911, and January, 1912, when the tide level of the outside water was for nearly one month $1\frac{1}{2}$ feet above mean level, the seepage was very noticeable, and the pumps were kept in operation a much longer time than when removing the run-off of rainfall only. This levee was built with a dipper dredge, and no muck ditch was cut in the base. It now appears that the falling earth did not penetrate the layer of muck and form a bond with the underlying silt. The seepage was so great on some parts of the levee during the above-mentioned period of high water that a ditch was cut along the middle of the levee for some 300 or 400 feet, and refilled with a dipper dredge. This method of refilling gave better results than that of hand filling and tamping, and rendered quite impervious the part of the levee so treated. The levee needs similar treatment for its entire length. The levee along the back or southwestern side of this district was built under conditions somewhat different from those attending the construction of the levees on the other three sides, this levee being located in the open water in the lake. The material placed in this levee was very soft, so that a number of layers were added before final completion. It was started in 1907, and the last addition was made in 1910. At first this levee was badly situated, as on the outside there was a canal having a depth of 6 feet, and immediately on the inside, with no berm between, was a reservoir canal with a depth of about 10 feet. The width of the levee at the level of the outside water was 35 feet, and more or less seepage occurred when the lake stood above its usual level for any length of time. At such times the head of water on the levee frequently was 7 or 8 feet. This seepage seemed to take place through defective spots in the body of the levee rather than through the base, for it was only when the water was above mean height for a considerable time that

¹ The side of a levee on which the protected land lies is termed the "inside."

seepage occurred. At ordinary stages of water the levee is hard and dry, although the base always is submerged. However, the condition of the levee was so unsatisfactory that during the latter months of 1911 a new reservoir canal was cut parallel to and about 40 feet distant from the old one, and the old canal was filled and considerable material deposited along the inside slope of the levee. This improvement should greatly reduce the seepage.

Experience on this tract seems to show that it is not good practice to place the reservoir canal immediately inside of the levee, especially if the base of the latter be below ordinary water level. Figure 7 shows cross sections of these levees, the stages of water in the canals, and the curve of the ground water through the levees at various times. It is apparent that there is considerable advantage in allowing a liberal cross section for such levees.

RESERVOIR CANALS.

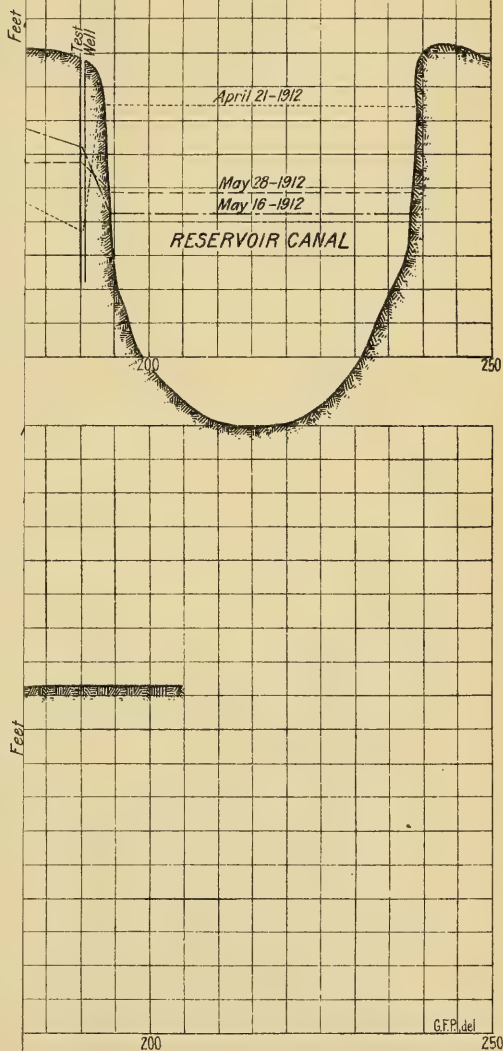
As this tract has a slope from front to rear of nearly 4 feet, the location of the reservoir at the lowest end of it was perhaps the best that could have been made to act as an outlet to the laterals. Originally it was about 35 feet wide and 5 feet deep. The storage capacity at this time was about 0.35 inch of water over an area of 647 acres. During the growing season of 1909 and the winter of 1910 it became partially filled with silt. In the spring of 1910 a 6-inch hydraulic dredge was employed to pump out this silt. The dredge did not work satisfactorily, but finally succeeded in taking out sufficient material to give the reservoir its former capacity. However, with a pumping capacity of about 1.1 inches in depth over the whole area in 24 hours the cross section of the canal was not large enough. After the water was lowered at the pump to the bottom of the canal it was still about 2 feet deep at the farthest part of the canal, a distance of 1.3 miles. It was then necessary to shut down the pump for perhaps 5 hours, after which an additional run of about 2 hours would take the water that had collected during the interval.

As above mentioned, this canal was reexcavated in 1911, and now has a depth of 8 feet and a width of 40 feet. The capacity is 0.45 inch in depth of water over the entire area. Even before the reservoir was reexcavated the combined capacity of the pumping plant and reservoir was sufficient to keep the land from flooding except for a few hours at times of extreme storm. With the larger canal the pumping plant is operated continuously until practically all of the water is removed.

DITCHES.

Due to the fall of about 4 feet to the mile in the surface of this tract it was considered feasible to extend the lateral ditches the full length, 1 mile. The ditches are of about the usual cross section—i. e., top width 4 feet, bottom width 1.5 feet, and depth 3 feet. They are spaced uniformly 160 feet apart. This seems to be a satisfactory arrangement, as the ditches have always given good drainage and have never been flooded for any great length of time. A length of 1 mile does not appear to be too great for ditches of this cross section and fall. In this case each of these ditches is draining about 25 acres of land, or carrying off 1.5 cubic feet per second on a basis of 1.5 inches run-off per 24 hours.

The cost of maintenance on these ditches is no small item. It is necessary to cut the weeds out of them at least twice each year and it is sometimes done three times. Once in two years it is necessary to take out about 1 cubic foot of material per linear foot. On this basis the annual cost of maintenance is



10. 2, showing water stages a

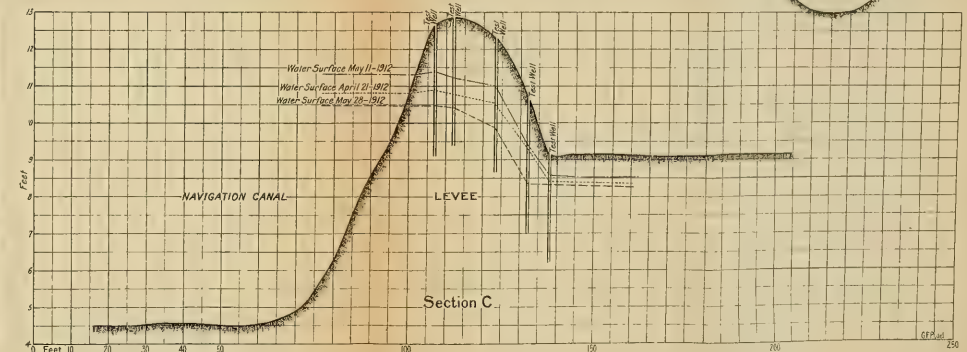
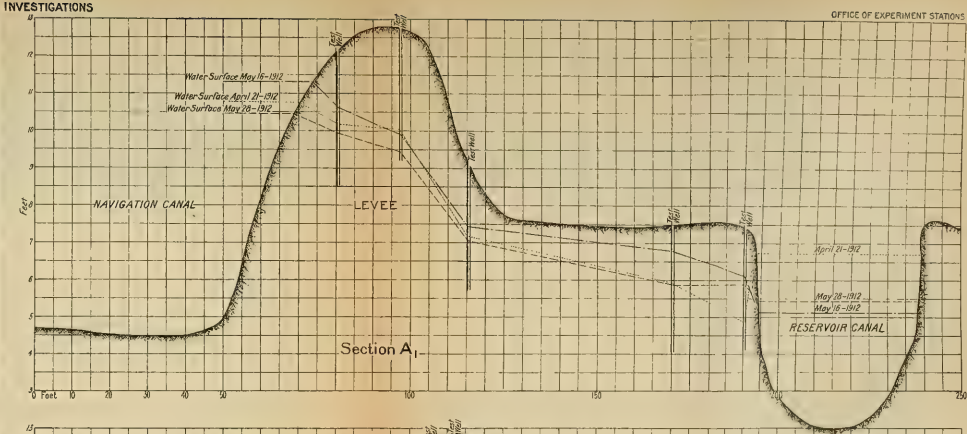
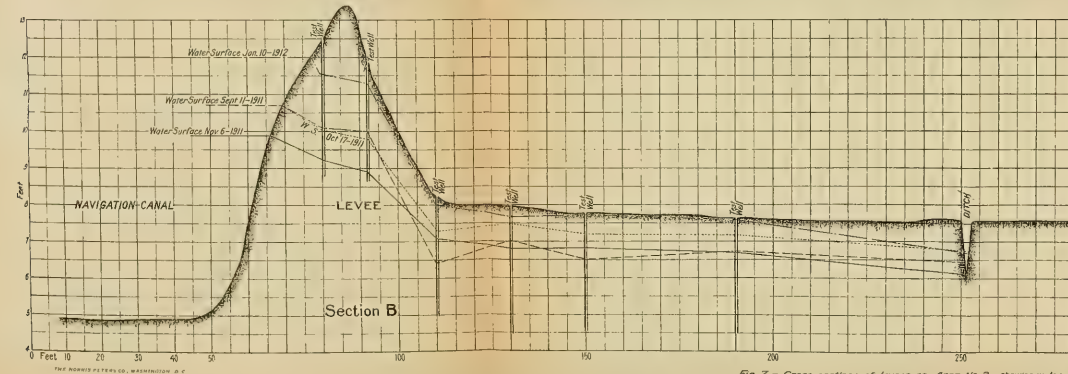
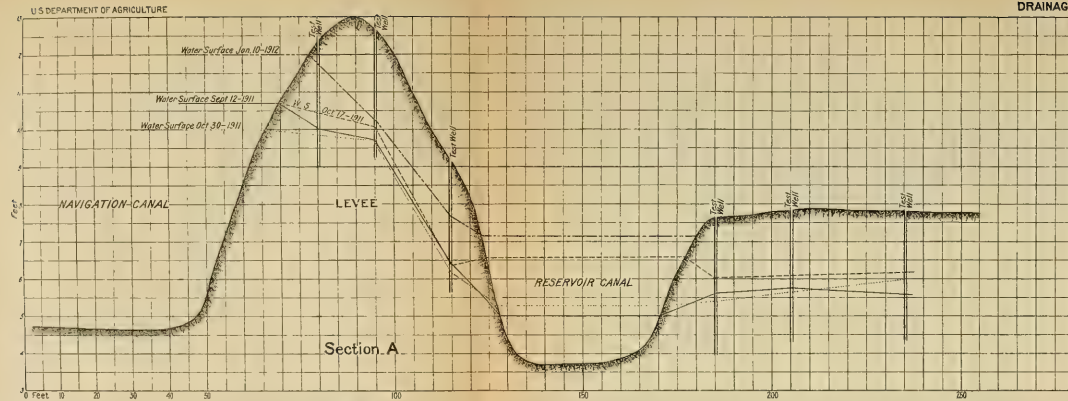


Fig. 7 - Cross sections of levees on Area No. 2, showing water stages and profiles of ground water (For locations of sections, see Fig. 6)

about \$0.75 per "acre"¹ of ditch. With the present spacing of 160 feet the annual cost of ditch maintenance per acre of area drained is about \$1.

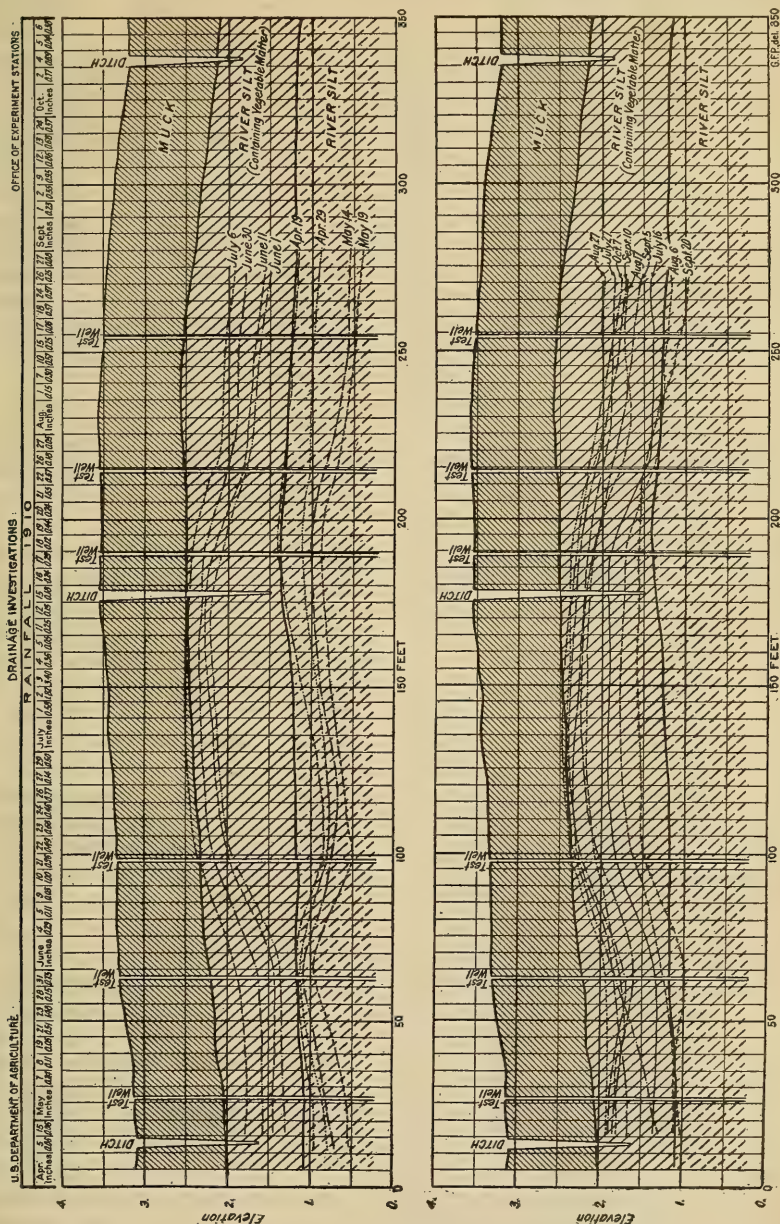
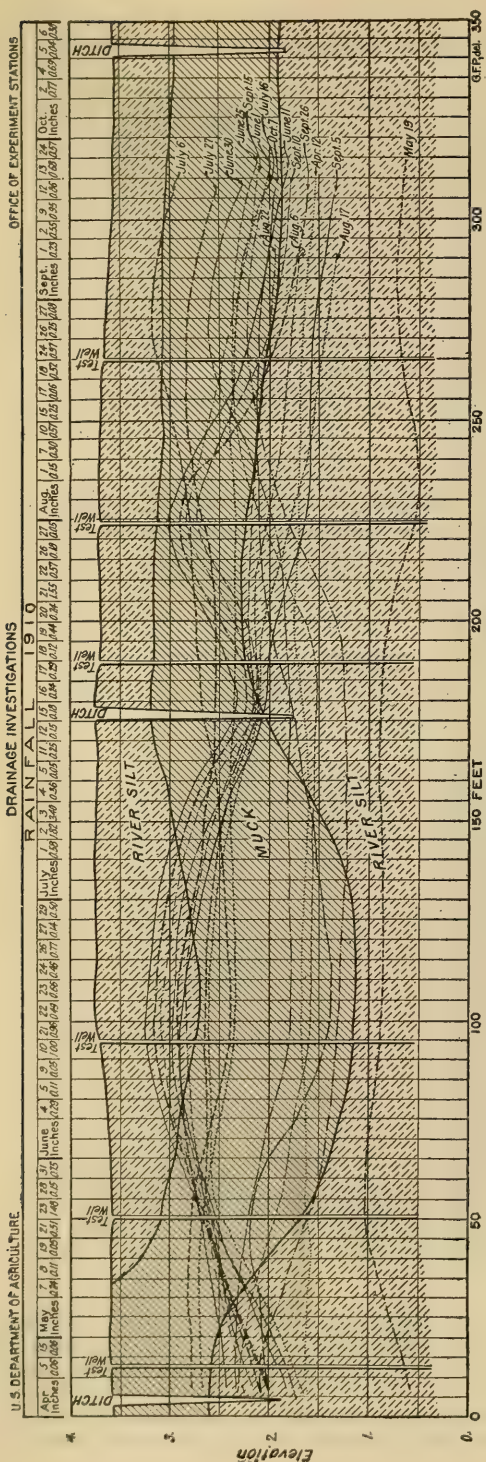


Fig. 8.—Profiles of ground water on interior of area No. 2.

During the summer of 1910 some measurements of the depth of the water table below the surface were made. The results of these measurements are shown graphically in figures 8 and 8a. It is evident that after long and heavy

¹ The term "acre" is in common use in the section under discussion as a unit of length in rough land measurements. Its value is the length of one side of a square whose area is 1 acre, or about 209 feet.



rains the ground water profile is quite steep, but that it rapidly flattens out. Although the silt on this tract is very fine grained and impervious, there is evidence of considerable lateral movement of the water through it. It was considered by the landowner that the depth of drainage was sufficient for the growth of crops. Corn was the crop on the ground at the time these measurements were taken.

PUMPING PLANT.

The plant is located at one end of the reservoir canal (see fig. 6, p. 28) and discharges by a short wooden flume directly into the commercial canal outside. There are two vertical centrifugal pumps of the square wooden-case type, with impellers 32 by 12 inches and 24 by 8 inches, respectively. Each pump is rope driven by a slide-valve noncondensing engine, steam being supplied by a 100-horsepower return-tubular boiler. A feed-water heater has been installed within the last two years.

As far as mere capacity is concerned, when running continuously, this plant is satisfactory. However, as regards reliability and efficiency, as well as cost of upkeep and operation, it is far from being an ideal plant. The chief trouble lies in the type of pump. The wooden-case pump with its rope drive is constantly giving more or less trouble; the expense for extra labor to repair the rope drive

added to the cost of new rope is a considerable item. The loss of power in the rope drive is unavoidable and the loss of the use of the pump at a critical time due to the breaking of a rope is a serious matter. This pump while adapted to a low lift is not suitable for a varying one. The total lift, to be on the safe side, must be about 1 foot above ordinary high tide, and when the variation of the tide is 2.5 feet with the effective lift only 4.5 feet, as it is in this case, it is apparent that the actual lift of the pump is often nearly twice the effective lift. Again, being made almost entirely of wood, repairs to this style of pump are frequently necessary, and as the parts to be repaired are usually under water the pump must be detached from the foundation and raised before the work can be done. These pumps while low in first cost are very short lived when compared to the cast-iron centrifugal type. Thus, considering the greater rate for depreciation and repairs on this style of pump as compared to the cast-iron centrifugal form, it appears that the latter might be preferable on this score alone.

A reliable pump if placed in this plant could be of considerable less capacity than the present ones and still be of ample size. The heaviest rainfall since the records of pumping have been kept occurred in July, 1910, when 5.58 inches fell in 2 days. A reliable pump with a capacity of 0.75 inch per 24 hours would have taken this water out rapidly enough to have prevented a longer flooding than 12 hours.

CONDITION OF LAND FOR CULTIVATION.

During the growing season of 1909 the front one-third of this tract was practically the only part that was sufficiently well drained to admit of cultivation. These front lands naturally were a little firmer than the portion that originally was a part of Lake Fields. The back portion was fairly well drained for two years previous to the season of 1909, but the land had not become firm enough to allow its cultivation with animal-drawn machinery. The drying out of these muck lands is accompanied by the formation of large cracks that extend to the soft mud below, and it is only after these cracks have been closed that cultivation can be done in the ordinary manner. The lateral ditches were all well cleaned and the silt was removed from the reservoir during the early spring of 1910. Although the spring of 1910 was unusually dry, all of the lake bed was not solid enough to be cultivated. Early in the spring of 1911 all this land was plowed with a gang of six turning plows drawn by a gasoline traction engine mounted on the apron traction instead of wheels. Corn was planted in this land and it was cultivated in the usual manner, since the one thorough plowing had completely filled the holes and cracks. The period necessary to bring the land under complete cultivation was about four years. This period could have been shortened if the drainage had been complete and continuous from the first and the land plowed a year sooner with a traction engine. Corn seems to be the easiest and best crop to grow on these new lands, followed by sugarcane the second and third years. Excellent yields of all kinds of truck have been grown on this plantation. Cane produces especially well and the tonnage per acre is very much greater than on the older lands along the bayou, exceeding their average nearly 50 per cent. No special treatment was given this soil when bringing it under cultivation and it does not appear that any was necessary.

AREA NO. 3, LA FOURCHE PARISH, LA.

This district (fig. 9) lies about 5 miles south of the village of Raceland and borders on the upper end of Lake Fields, this being the same lake from which a part of area No. 2 was taken. The district contains 940 acres. The surface

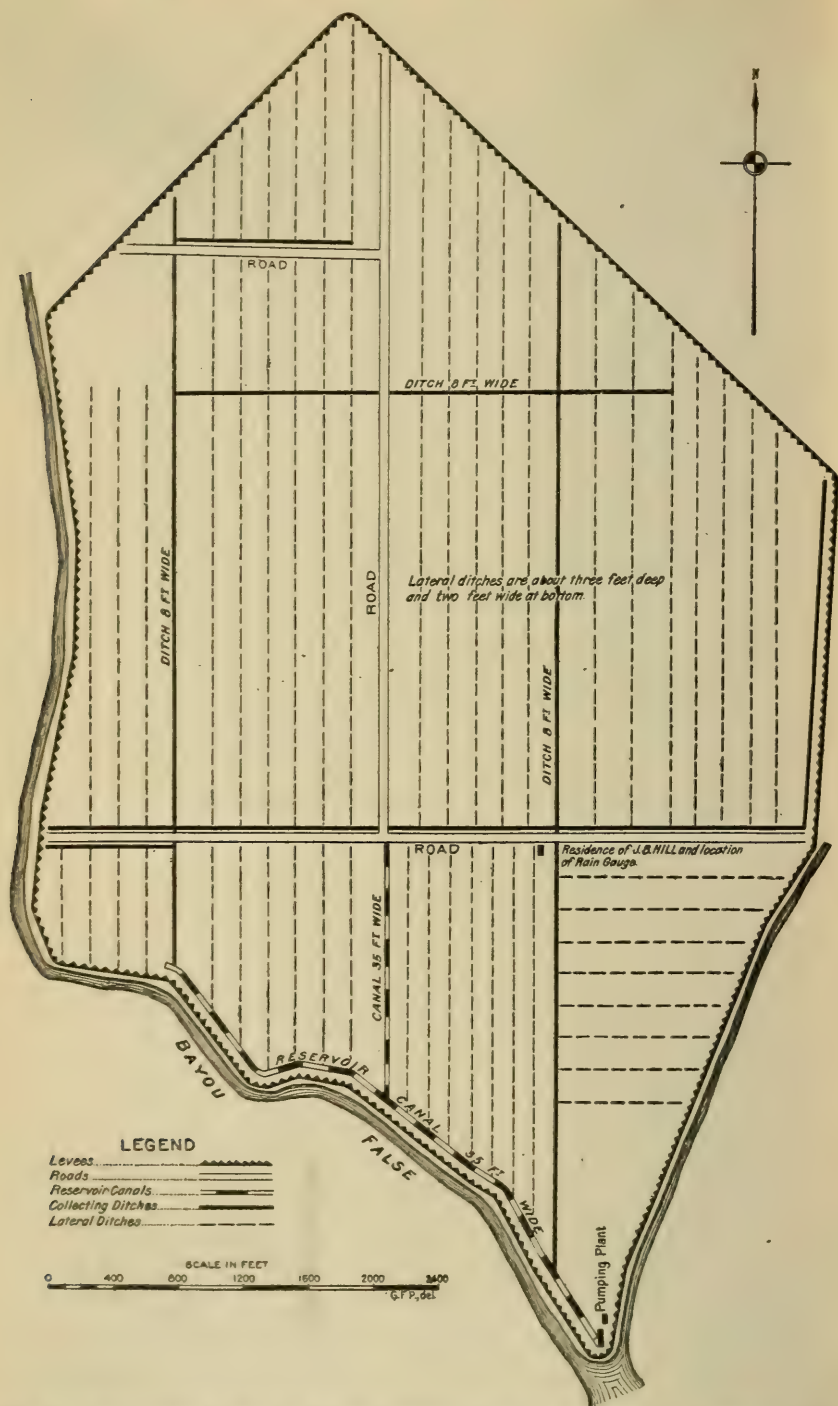


FIG. 9.—Sketch map of area No. 3, near Raceland, La Fourche Parish, La., showing ditch and levee system.

slopes gradually from a height of about 3 feet above mean tide at the north end to lake level at the south. Reclamation on this tract was started in 1907, and the first extensive cultivation was done in 1909. The condition and general character of the muck has previously been described in the discussion of muck soils. (See p. 12.)

LEVEES.

For the most part the levee was built of material taken from the outside of the district. The work was done with a dipper dredge with a short boom, and the berm on the outside is very small and in some places entirely lacking. The levee was gone over two or three times before it was brought to its present height of 4 feet above mean tide. The present crown is about 4 feet wide and the side slopes are nearly as steep as 2 to 1. When this levee was built no muck ditch was made in the base nor was any of the surface cleared of vegetation. The levee was cut by a trench some months after it had been built. This showed that the material, when placed, did not force its way through the muck and form a bond with the underlying silt. At this point the muck was quite turfy in character, but not more so than the average muck of this part of the prairie. The layer of muck under the levee was considerably compressed, but it certainly was still quite pervious when compared to silt. The fact that the base of this levee is above ordinary outside water level probably accounts for the fact that no great amount of seepage appears. In the lower and softer part of the district some of the material in the levee was taken from the reservoir canal. Here a berm of from 10 to 15 feet was left between the levee and the canal, the muck being so soft that the mud, when dropped from the dipper, undoubtedly cut through the muck to the silt below. The same condition existed here as gave trouble on area No. 2, except that there was a berm on the inside of this levee and the difference in the level of the water inside and outside was never as great as on area No. 2. If the reservoir had been of sufficient depth to drain thoroughly the lowest land in this district, the head of the water against the levee might have been great enough to cause a noticeable amount of seepage. During the fall of 1911 the reservoir was deepened about 3 feet and the material placed on the levee. As the levee has had a chance to harden for several years since it was first built, it is not expected that this increased depth of drainage will cause a greater amount of seepage through it. In this case no damage seems to have resulted from placing the reservoir canal close to the levee and from using the material excavated from it for levee building.

During the unusually high stage of water in this lake in December, 1911, and January, 1912, the levees on the higher part of the district leaked very badly, as might have been expected from a previous examination of the unbroken layer of muck in the base. In the softer portions of the district no great trouble was experienced from seepage. During the early months of 1912 a continuous muck ditch was cut along the toe of the inside slope of these levees and this refilled with material taken by an orange-peel bucket dredge from the bottom of the outside canal. The levees should now be in much better condition to resist seepage.

RESERVOIR CANALS.

When this reservoir was first excavated the ground was very soft; as a result a deep layer of mud was soon deposited in the bottom. Owing to the fact that it was located in the lowest part of the tract it served as an outlet to the lateral ditches, but never was of sufficient capacity to aid in reducing the

required capacity of the pumping plant. The surface of the ground for a considerable distance around the pumping plant is much lower than that of the remainder of the district, so that the water was allowed to overflow the reservoir and to fill this low area. As no attempt was being made to cultivate this low area it was used in this manner for additional reservoir capacity. If an attempt had been made to reclaim the entire district the reservoir must have been found too small for any practical use, but by allowing this low part of the tract to be flooded the remainder was given fairly good drainage until the summer of 1911. The need of a better reservoir then became apparent and during the month of October the reservoir was excavated to a depth of 7 feet and a width of 35 feet. In addition to cleaning out the old canal a new portion was cut into the central part of the district. The capacity of the new reservoir above a 4-foot level is 0.25 inch; the reservoir should maintain this capacity, as the surrounding ground is quite firm. In excavating along the old reservoir the material was found to be solid enough for each dipperful partially to hold its shape after being dropped on the spoil bank. Considerable difficulty was encountered, however, in removing the soft mud that had collected in the bottom of the reservoir. A hydraulic dredge would have been much more satisfactory for taking out this mud.

DITCHES.

During the first two years of cultivation on this tract lateral ditches of a depth of 3 feet, spaced as far apart as 600 feet, gave ample drainage. Due to the short length of reservoir canal it was necessary to construct some large collecting ditches to keep the lengths of laterals from being too great. These collecting ditches were about 8 feet wide and 4 feet deep, but as they were frequently nearly dry a strong growth of vegetation soon reduced their effective size very greatly. They did not afford the small lateral ditches sufficient outlet and consequently the tract was not well drained; at the same time the ground was becoming more impervious, due to the decay of the muck. Lateral ditches were then placed about 200 feet apart and the ditches were cleaned out. During the summer of 1911, one of unusual precipitation, it was found that about halfway between adjacent lateral ditches the ground was saturated with water to the surface. Some of the landowners now propose to place lateral ditches as close together as 100 feet. It would seem that this is as yet unnecessary. In the first place, the laterals were not at that time of the usual depth of 3 feet; they were not kept in good condition, and some of them were nearly three-fourths of a mile long, and furthermore the reservoir canal was not of sufficient depth to keep the water out of these ditches. If the above defects were remedied, it certainly would improve conditions greatly and might make the cutting of additional ditches unnecessary. The use of a collecting ditch instead of frequent reservoir canals, while it reduces the first cost of the drainage channels is rather unsatisfactory. The collecting ditch soon becomes grown full of weeds and grass, while a small reservoir canal will always have water in it and will not so easily become obstructed. Plate I, figure 1, shows an apron-traction ditcher cutting laterals on this district.

PUMPING PLANT.

The plant is located in the lowest part of the district. The pumps discharge through a short wooden flume into the lake. There are two 32 by 12 inch vertical centrifugal pumps of the square wooden-case type. One of them is belt driven and the other rope driven, each by a 12 by 16 inch slide-valve noncon-

densing engine. Steam is furnished by two 60-horsepower locomotive type boilers. The machinery is on a timber foundation, supported on piling, and the building is a frame structure covered with heavy corrugated galvanized iron. In type the plant is very similar to the one on area No. 2 and is subject to the same general criticisms. In capacity it has always been sufficient, but due to the small reservoir it could only be operated at full capacity for rather short periods. However, the new and large reservoir remedied this difficulty, although on account of its length the collecting ditch will always bring in the water rather slowly.

The present conditions are favorable to a small percentage and a low intensity of run-off. As the district is more completely brought under cultivation, however, and the water is more promptly pumped out, both the amount and the intensity of the run-off should increase, although it is not likely that this will be large enough to require an increase of the present large pumping capacity. In August, 1911, this plant burned; it was reconstructed, the present plant being a duplicate of the former one. In a plant of this character, where most of the structure is of wood, the danger of fire is much greater than in the more recent type of pumping plant. These latter are equipped with cast-iron centrifugal pumps mounted on concrete foundations and are built with some idea of making them fireproof.

CONDITION OF LAND FOR CULTIVATION.

In bringing this land under cultivation the first crop was planted on the higher portions after a year of drainage. Before the muck became decayed it drained very readily, and, as stated on page 36, few laterals were necessary. Good crops of corn were grown on this land with the water table only 1 foot below the surface. Sugar cane has also successfully been grown on this land, as have all kinds of truck. No special treatment has been given the land before cultivation. Not all of this district has been cultivated, though it is now all solid enough to be easily cultivated if the water were kept sufficiently low. This tract could have been brought under cultivation much sooner if it had been well drained the year around, instead of only during the growing season. In draining new land it is important to keep it well drained all of the time, so that the soft mud will have a chance to harden.

AREA NO. 4, RACELAND, LA FOURCHE PARISH, LA.

This district, containing 2,400 acres, is similar in natural conditions, such as soil and elevation, to area No. 3, and borders it along one side. While in size it is more advantageous than any of the districts heretofore mentioned, its shape, due to natural boundaries, is not as good. However, the various details of reclamation have been somewhat better carried out in this district than in those previously discussed. The map of area No. 4 is shown in figure 10.

LEVEES.

Most of the levee was built by a dipper dredge with material taken from the channels which the map shows outside the protected area. No ditch was cut in the base of the levee nor was any other preliminary work done. Along Bayou False the levee was built from material taken from both inside and outside the district. This bayou had been opened for navigation several years before the levee along this district was built. The spoil bank had settled until it was quite firm, so that the material taken from the reservoir canal, when deposited on this firm base, formed a levee of sufficient cross section the first time over

with the dredge. Along most of the boundary of the tract the ground was so solid that once over with the dredge, cutting a 35-foot by 6-foot canal, gave more than enough material to build a levee. The average height of the levee is 4 feet above mean tide, and the top width, while variable, averages about 5 feet. All of the levee has not been brought to an even grade as yet, and much

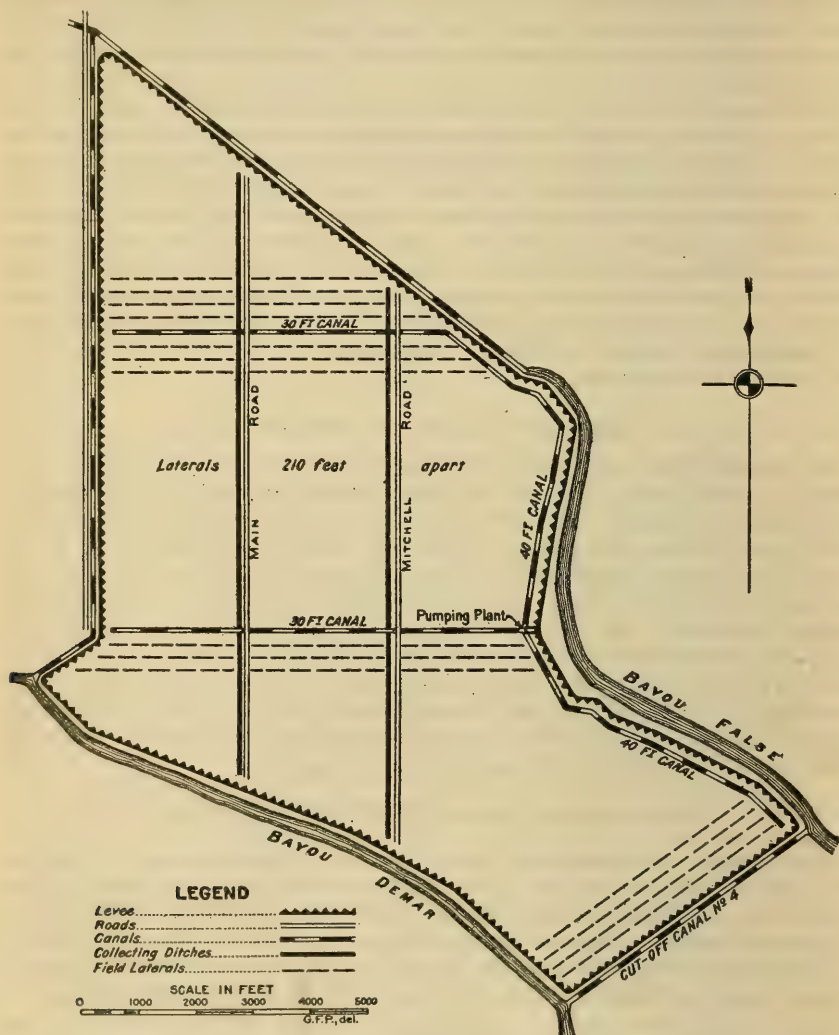


FIG. 10.—Sketch map of area No. 4, Raceland, La Fourche Parish, La., outlining arrangement of ditches and levees.

of it has been allowed to grow up in weeds. As far as can be noticed, this levee is practically free from any great amount of seepage at ordinary water level. For the most part the base is above mean tide, and no doubt this fact partly accounts for the good condition of the levee. Where the reservoir canal parallels Bayou False a 10 to 15 foot berm was left along both sides of the levee, making the total distance between canals nearly 60 feet. On the other portions

of the tract the berm along the outside of the levee is smaller and averages about 5 feet in width. As ditches do not parallel this levee except on one side, and then not closely, the small width of berm should not prove a serious defect as far as seepage is concerned.

As stated on page 37, no muck ditch was cut in the base of the levee, and at ordinary stages of water no large seepage was apparent. However, during the high water that affected area No. 3 the levee leaked badly, and, as was the case in area No. 3, the water seemed to come through the base where the layer of muck occurred, rather than through the body of the levee itself. This defect was remedied by cutting a ditch along the slope of the levee and filling it with material dredged from the bottom of the canal. This not only cut off seepage through the base of the levee, but added somewhat to the cross-sectional area.

RESERVOIR CANALS.

Owing to the size of this tract it was necessary to cut reservoir canals into the interior to give outlet to the system of laterals. This rather extensive length of canals gives a larger reservoir capacity than is had in any of the other districts of this vicinity. Between the surface and a distance of 4 feet below these canals have a capacity of 0.40 inch of water over the entire area. It is possible for the pumping plant to lower the water below this level, but under ordinary circumstances this is approximately the level to which the water is reduced. The added depth of reservoir (the canals are nearly all over 6 feet deep) will be of service in reducing the velocity of flow in the canals during the time of pumping and also in keeping their bottoms covered with water. This last feature will in a measure prevent the growth of weeds and grass and the consequent choking of the canals. In December, 1911, these canals were quite badly filled with a deposit of soft mud, 2 and even 3 feet having been deposited in places since the cutting of the canals some two years previous. This deposit is quite rapid during the first year of drainage. It is due partly to the wash from the laterals, but also to the crumbling and the sliding of the sides of the canals. The sliding is especially great when water is lowered too rapidly when the district is first pumped out. By taking the water out very gradually it has been found that, even when the canals have been cut in very soft material, any great amount of sliding of canal banks can be avoided. In the softest portions of the prairie it has been found that there is a tendency for the surrounding mud to flow toward the canals when the water is lowered for the first time; the walls of the canals may continue to be even and unbroken, but the canals do not remain as wide nor as deep as they were before the water was lowered and this flow began. The material on this tract was too solid for any considerable amount of flow to be apparent. During the early part of the month of December, 1911, an 8-inch hydraulic dredge was started in these canals to remove this deposit of mud. It was found desirable on the larger canals to replace the hydraulic dredge with an orange-peel-bucket dredge. By cutting into the harder underlying material it was possible to remove most of the soft mud from the bottom of the canal. This redredging of interior canals seems to become necessary from two to four years after they are first cut.

The reservoir has thus far given satisfaction in the reclamation of this tract. The increase of lift during the operation of the pumps, due to the slope of the water surface, is quite small. The greatest length of canal tributary to the pumping plant is about $2\frac{1}{4}$ miles. The greatest length of drainage channel that the water travels is nearly 3 miles.

DITCHES.

In this district, as in area No. 3, the collecting ditches have been used in connection with the lateral ditches to drain the ground. The collecting ditches have been placed along the roads and this has made it less difficult to keep them in good condition and also to see when they were in need of cleaning. However, these collecting ditches have not been easy to maintain, and it has been necessary to clean them out a number of times. It was the plan at first to place the laterals every 210 feet, but later they were placed at twice that distance. When the ground was first drained this greater distance was not found to be too great. In 1912, after two years of drainage and cultivation, a distance of 210 feet is considered by the landowners to be about as great as is safe. The laterals were at first 3 feet deep. This depth is not considered sufficient when the spacing between the laterals is as much as 210 feet. At times of heavy rains it has been found that the land between the ditches became too wet for best growth of crops.

Most of the laterals on this tract carry drainage water for at least 2,000 feet. This length seems to be allowable if the ditch is kept in fairly good condition. When ditches longer than a half mile are used, they must be increased in width and depth at the lower end, unless they are kept in perfect condition all of the time. On the lower and softer portion of this tract, unless some further collecting ditches are cut, the length of lateral will be nearly a mile; in view of the fact that this ground is almost level it is likely that this length will be too great. The percentage of land consumed in ditches and canals on this tract is quite small, considering the large area in reservoir. When all of the ditches are spaced 210 feet apart the area of land so consumed will be a little more than 2½ per cent.

PUMPING PLANT.

The pumping plant is quite well located to draw water from all parts of the district. The discharge is into Bayou False, which is about 60 feet wide at this point and so affords an excellent outlet. As this plant is of much better construction than any of the others of this group, a somewhat detailed description of it will be given (see fig. 11). The block of concrete which forms the foundation for the pumps and engines is about 17 feet wide and 50 feet long, and was placed approximately on the center of the levee with its greatest length parallel to the levee. This block is 8 feet thick and so extends below the plane of permanent water level, thus protecting from decay the piling that supports it. Around this foundation was driven a double row of sheet piling, and at each end a double row was extended some 15 feet into the levee. The sides of the intake basin also were protected by a double row of sheet piling, supported by a timber frame bolted to a number of round piles. The short length of discharge canal necessary to reach to the bayou was protected in a similar manner. Across the front of the intake basin a wooden screen prevents any floating matter of size from entering the pumps. The base of the pumps is set at about extreme low water in the bayou, and to protect the foundation from being flooded the concrete is raised in a wall about a foot thick along the outside to a height of 3 feet above mean tide. The whole of the foundation is well reinforced with steel, and the round piling under the concrete extends into it about 2 feet, thus insuring a perfect bond.

One 30-inch cast-iron centrifugal pump was installed in March, 1910, and a duplicate unit was added July, 1912. The arrangement and size of piping of the first unit is shown in figure 11. The important features are the enlarging and tapering of the pipes at the intake and discharge ends, the freedom from bends or elbows, and the horizontal cutting of the intake end of the pipe, the

latter feature permitting the water to be lowered to the end of the pipe without allowing the entrance of air. The saving in velocity head losses secured by enlarging the pipes amounts to nearly 2 feet, which is about one-half the usual lift. The pipes are supported by steel hangers secured to pairs of round piling. The pump is driven by a 14 by 16 inch vertical slide-valve engine, direct connected to the pump shaft with flexible coupling. This style of engine occupies less floor space and also requires shorter lengths of pipes on the pumps than does the horizontal type. In addition, it is less likely to cause vibration or motion of the foundation when operated at high speed. Steam is furnished by a return tubular boiler burning crude oil. The building for this machinery has a timber frame covered with heavy corrugated galvanized iron. The theoretical capacity of the completed plant, when both pumps are working

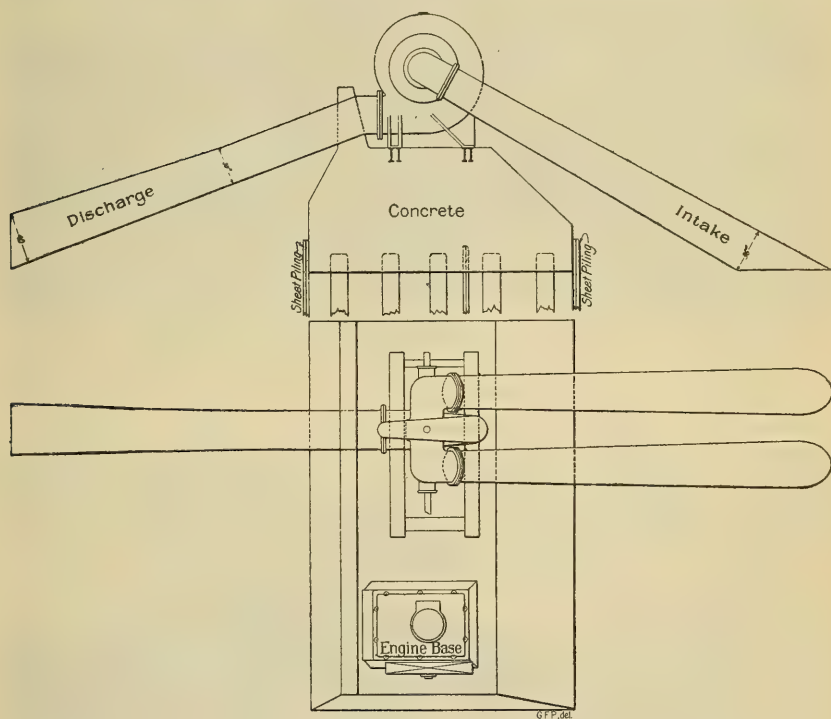


FIG. 11.—Sketch plan and elevation of one unit in pumping plant of area No. 4, Raceland, La.

most economically, will be 1 inch per day with a maximum of 1.4 inches per day. One pump, with a capacity of 0.7 inch per day, successfully drained this tract for nearly two years until the time of high water in December, 1911, and January, 1912, when, owing to the seepage through the levee in addition to the rainfall, the ground was flooded for two or three days. At this time the reliability of this plant was shown, as the pump was operated continuously for six days and nights. With the second unit installed, no trouble should be experienced in removing any rainfall encountered, especially since the levees are now much better able to keep out seepage. It is quite certain that when all of the tract is under cultivation and all lateral ditches are in operation the intensity and amount of the run-off will be largely increased, but, due to the large reservoir capacity of the plant, no trouble should be encountered.

CONDITION OF LAND FOR CULTIVATION.

The pump was first started on this tract about March, 1910. The canals had been cut some months before and the lateral ditches had also been in operation on the higher portions for about the same length of time. Some 300 acres of land were brought under cultivation during the spring of 1910, a large part of it by the use of horses and ordinary farm machinery. The remainder of this 300-acre tract was broken with a pulverizer attached to an apron-traction-ditcher frame. During the season of 1911 about as much more area was brought under cultivation. Nearly all of the tract that had been ditched could have been cultivated from the first. Much of the land in the lower portion of the tract is not yet completely ditched; in this part the ground is still far too soft to allow the use of horses or mules and ordinary farm machinery.

The general crop grown was corn, with a small acreage of cane planted in 1911. Both crops were uniformly good, the cane being especially heavy.

AREA NO. 5, DES ALLEMANDS, LAFOURCHE PARISH, LA.

This tract of land (fig. 12) is one of the newest of the reclamation districts, and has only been under drainage since September, 1911. It lies on the western side of Bayou des Allemands, which at this point is several hundred feet wide and from 10 to 15 feet deep. The district contains 1,880 acres and includes a portion of the village of Des Allemands, lying on the western side of the bayou and south of the Southern Pacific Railroad. The land is 1 or 2 feet above ordinary tidewater in the bayou, and a large percentage of it is made up of firm silt ridges, with a very thin layer of muck on the surface. At intervals there occur old muck-filled bayous, having widths of from 100 to 200 feet and depths of from 10 to 15 feet; however, the land is mostly quite firm, the proportion of such soft ground being about 10 per cent. Some of it was solid enough to plow in the ordinary manner as soon as the water was removed by the pumps. Except for a few scattering trees on the high ridges, most of the tract is covered with a heavy growth of the natural prairie grass. The muck averages from 8 to 12 inches in depth and is quite turfy in character.

LEVEES.

On two sides of this tract the problem of levee building was a simple one. The embankment of the Southern Pacific Railroad makes an excellent levee on one entire side and on the side that borders the bayou the solid ridge of silt was almost continuous and averaged about 2 feet above mean tide. Twice over with the dredge along the bayou made a levee about 5 feet high and having a top width of from 8 to 12 feet. The side slopes on this part of the levee are about $1\frac{1}{2}$ to 1. It is expected to use this part of the levee for a road, and as the material is almost pure silt it should make an excellent roadway. After the first layer of material was placed in this levee a muck ditch was cut along its inside slope. When the second layer was placed this ditch was filled with pure silt taken from the bottom of the levee canal. This should give a levee that will be free from any great amount of seepage through the base. On the other two sides of the district canals had been cut some years before and the material thrown on both sides. This left a low solid base for the levee, and in most places once over with the dredge gave a levee 3 or 4 feet high with a top width of from 4 to 6 feet. The side slopes on this portion of the levee are from 2 to 3 horizontal to 1 vertical. The berm varies from 5 to 10 feet. Except where some old muck-filled bayous are crossed, the levee is high enough to pre-

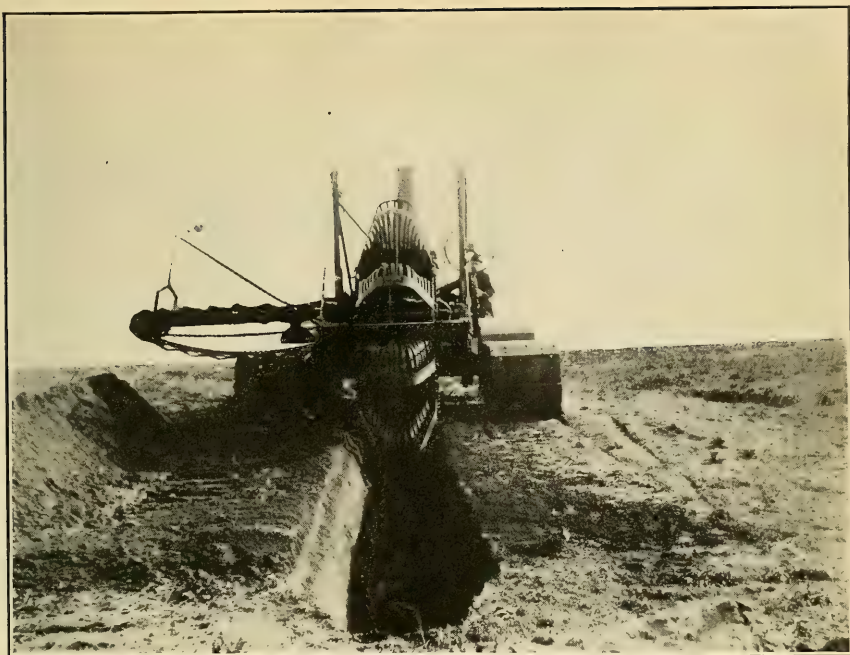


FIG. 1.—APRON-TRACTION DITCHER CUTTING LATERAL DITCH ON AREA NO. 3, RACELAND, LA.

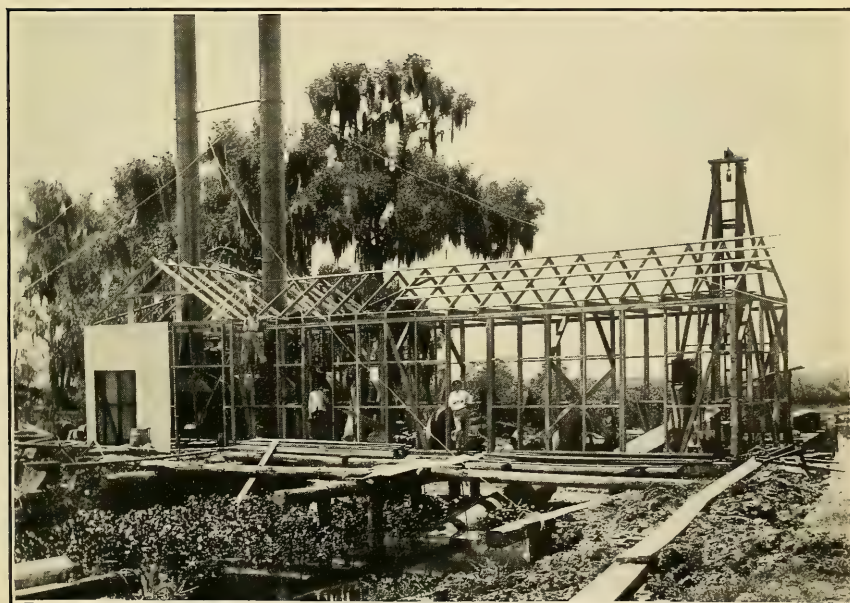


FIG. 2.—PUMPING PLANT (UNDER CONSTRUCTION) ON AREA NO. 5, DES ALLEMANDS, LA.



FIG. 1.—VIEW OF WET PRAIRIE BEFORE RECLAMATION.



FIG. 2.—APRON TRACTOR PULLING GANG OF BREAKING PLOWS AFTER RECLAMATION, AREA NO. 7, GUEYDAN, LA.

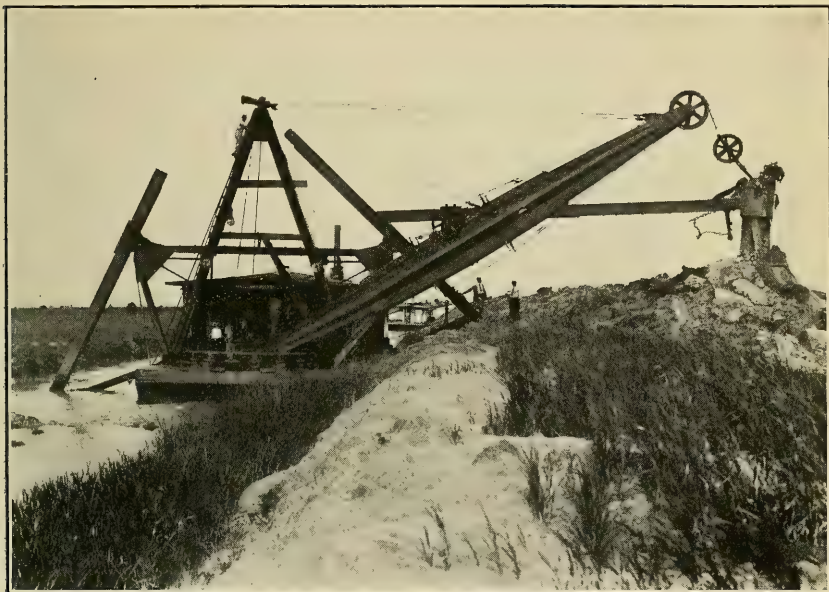


FIG. 1.—DIPPER DREDGE CUTTING 50 BY 10 FOOT RESERVOIR CANAL AND BUILDING LEVEE.

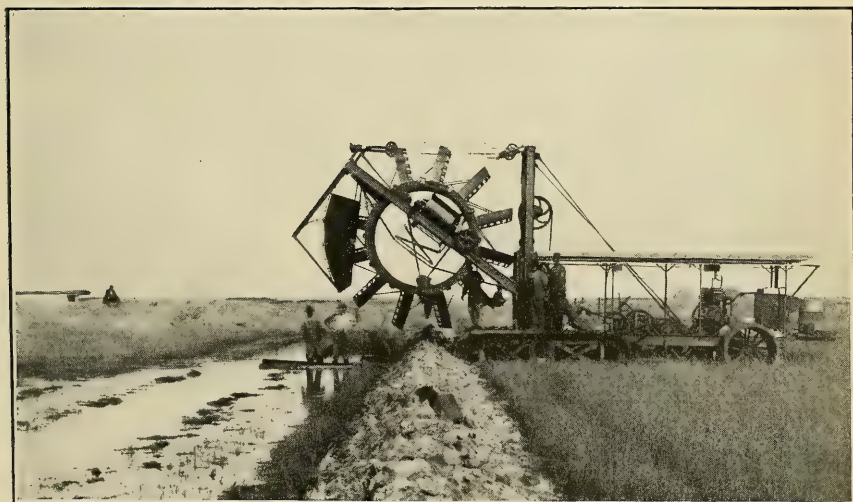
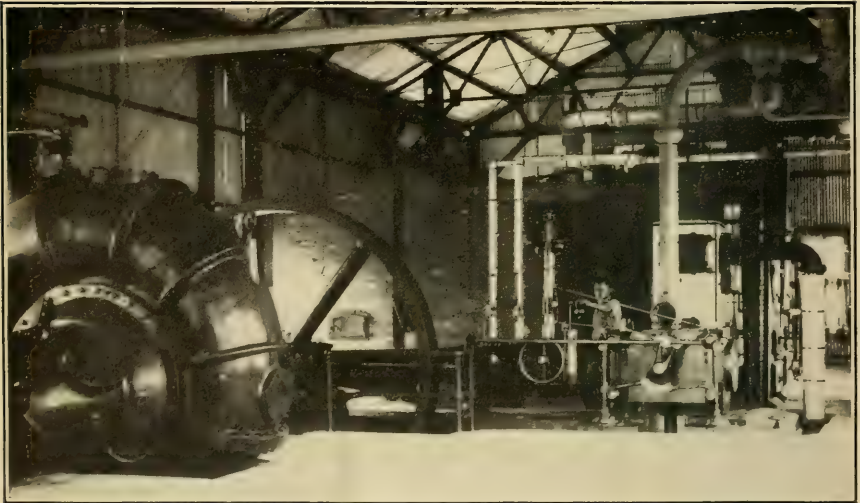
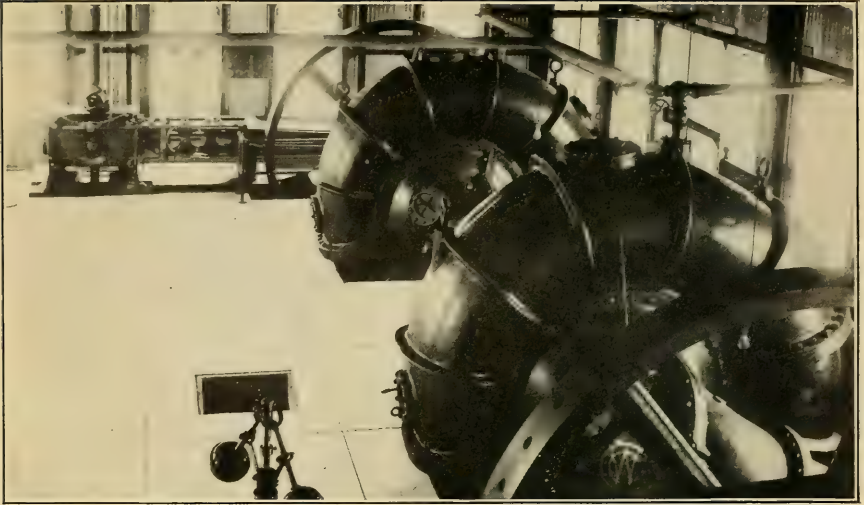


FIG. 2.—APRON-TRACTION DITCHER CUTTING LATERAL DITCH, AREA NO. 7, GUEYDAN, LA.



INTERIOR VIEWS OF PUMPING PLANT ON AREA No. 7, GUEYDAN, LA., SHOWING ARRANGEMENT OF ENGINES AND PUMPS.

vent flooding. In these soft spots the levee is only about a foot above mean tide and considerable work will have to be done to bring it to grade. Additions are being made to these portions with hand labor, and at present subsidence has practically ceased.

On a portion of the levee where the old bank was used for a foundation some peculiar seepage conditions have become apparent. Water appeared in the interior of the district some 20 to 40 feet from the levee, and an examination showed that the subsoil of the impervious Sharkey clay was filled with holes that varied in size from that of the usual crawfish hole, about 1 inch in diameter, up to several inches, the latter probably being muskrat holes. This was in a place where the underlying subsoil was very solid. It will be necessary to cut a deep muck ditch along this levee and fill it with puddled earth.

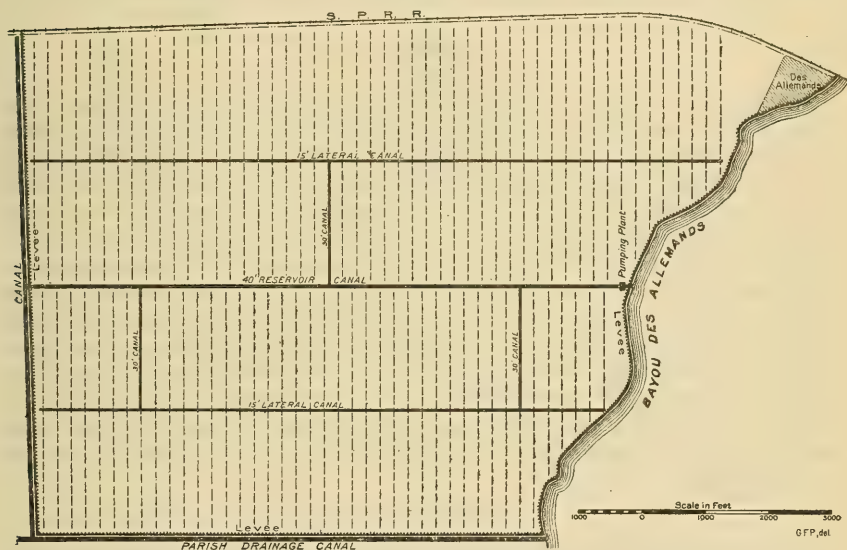


FIG. 12.—Sketch map of area No. 5, Des Allemands, La Fourche Parish, La., showing arrangement of levee and ditches.

RESERVOIR CANALS.

As shown in figure 12, the reservoir canals were all cut in the interior of the district. By extending the canals to all parts of the tract the necessity of small collecting ditches was eliminated. A small canal gives much better outlet to the laterals than a collecting ditch and is easier to maintain in good condition. These canals were cut with a dipper dredge and the material was deposited rather close to the sides of the canal. This resulted in a small amount of shrinkage in the size of the canals, there having been, in February, 1912, about 4 feet of soft mud in the bottom of each of them; part of this was perhaps left by the dipper dredge when cutting the canal. It was expected that an attempt would soon be made to remove this mud with a small hydraulic dredge; this should be a very favorable situation for its use. At the time of the examination the cross section of the main canal was so far reduced that the pumping plant could not be operated at full capacity after the water was

reduced to about 3 feet below the surface. The water was lowered very slowly in the canals, beginning about the 1st of September, 1911. No large slides occurred until about the end of December. At that time the water was lowered to the bottom of the canal and the banks became very soft, due to heavy and continued rains. In the immediate vicinity of the pumping plant, where the water was the lowest, and where an old muck-filled bayou was crossed, both sides of the main canal caved in for a length of about 200 feet. The surrounding ground surface for a distance of 100 feet was lowered by this action. The foregoing is a good illustration of the way this material will flow when conditions are favorable. The capacity of the reservoir system when it is brought back to its original size will be about 0.5 inch between the surface and a 4-foot level. This should bring the water to the pumps in sufficient quantities to keep both of them in operation until the water in the canal is lowered to at least a 4-foot level.

DITCHES.

The spacing of ditches on this tract probably will be about 200 feet. It is likely that on the higher and more solid portions the ditches will not require such close spacing as this, at least for the present. The ditches were being cut with a ditcher similar to those usually employed on land of this character and will be of the usual size. They will discharge into the small canals and none of them will connect directly with the main reservoir canal. The idea is to cause the silt to deposit in the small canals and thus leave the large canal free from mud. Owing to the regular shape of the district and the regular arrangement of the canals the ditches will all be of about the same length and the whole tract should receive about the same degree of drainage. The length of ditch will be nearly 2,000 feet. With the good outlet that the canals will afford, when compared with collecting ditches, this length should not prove to be too long to afford good drainage. If the ditches are placed at the usual spacing of about 200 feet the proportion of land in ditches and canals will be 3.6 per cent.

PUMPING PLANT.

The pumping plant is located about 300 feet back from the bayou front, on a leveed outfall canal. The plant was thus located in order that advantage might be taken of a firm ridge of silt as a foundation for the machinery. The arrangement and character of the foundation are shown in figure 13 and are very similar to those of the foundation under the plant on area No. 4. In this plant there are two units, which are duplicates. The pumps are cast-iron centrifugal with a 24-inch diameter of discharge. Plate I, figure 2, shows this plant under construction and gives an idea of the arrangement of boilers and machinery. The discharge and intake pipes are both enlarged and tapered the full length. The area of the intake pipe is about four and one-half times and the area of the end of the discharge pipe is nearly three times that of the discharge opening on the pump. This enlargement saves a loss of velocity head of nearly 4 feet, which is about equal to the ordinary actual lift of the pumps. The intake pipes have but the one elbow where they enter the pump and the discharge pipes are both straight. These pumps should operate very efficiently, as everything possible has been done to cut out unnecessary losses. To each pump a 12 by 12 inch simple vertical engine is direct connected with a flexible connection. Steam is furnished by two return-tube boilers burning coal. Oil burners are now being installed. This plant has been in operation since September, 1912, and is running very smoothly. Both of the units have been run continuously for a period

of 4 or 5 days and were in good condition at the end of the run. This type of plant seems to give the reliability that is necessary in a drainage plant. Its theoretical capacity when operating at full load is 0.95 inch of depth in 24 hours.

AREA NO. 6, NEAR POYDRAS, ST. BERNARD PARISH, LA.

This district is part of a tract of 85,000 acres of land that lies to the south of the little town of Poydras, in St. Bernard Parish, being about 15 miles from New Orleans. The front boundary of the tract is for the most part the back line of the river-front plantations and the land extends back several miles. Most of the area is open grass-covered prairie, with only a narrow belt of timber near the front line. As a whole it is almost at mean tide level, the average elevation being not far from 0.5 foot. The muck is close to 4 feet deep and is not quite so turfy in character as is that in the vicinity of Race-

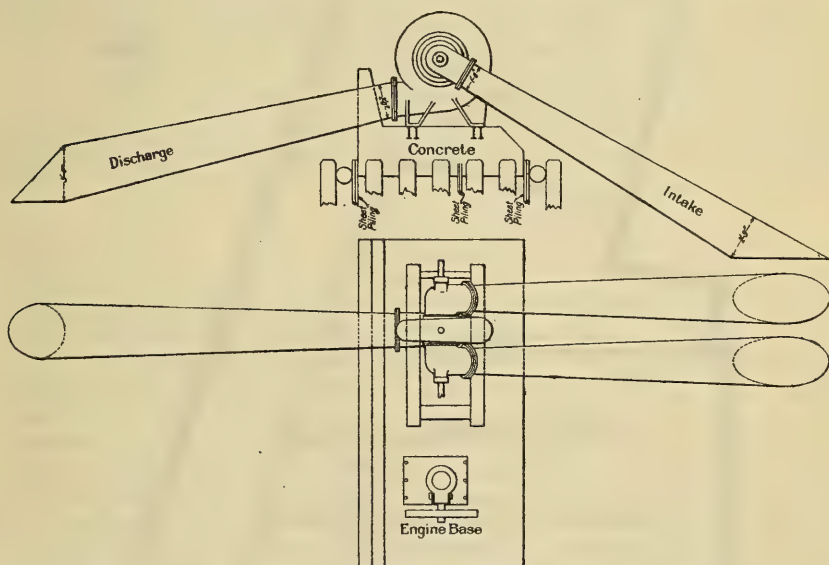


FIG. 13.—Sketch plan and elevation of one unit in pumping plant on area No. 5, Des Allemands, La.

land and Lockport. It seems to be the result of the decay of the usual growth of prairie grass, but has considerable silt mixed in with the decayed vegetable matter and lies on a subsoil of typical Mississippi River silt, of chocolate-brown color. Owing to the slight elevation of the land it is quite soft, since it has never had a chance to drain and become solid. The front part is not cut up to any extent by bayous, although the tract includes a lake with an area of nearly 5 square miles.

The greatest problem to be solved in the reclamation of this tract is the protection against storm tides. The maximum rise in tide at this point is between 5 and 6 feet. This is higher than any on record for a period of about 100 years previous to the storm of September, 1909, which gave this maximum height.

Area No. 6 contains 2,000 acres of open grass-covered prairie taken from the above-described tract of land and in addition contains 500 acres of a river-front plantation. It is so located that an addition to it can be made on the west side if the pumping plant proves larger than necessary.

outside they will be made useful for navigation. For the most part there was no preparation of the base of the levee, for when the first few dippers of material were placed in the levee it cut very deeply into the muck and formed a good bond with the underlying silt. In placing the first layer no attempt was made to get much above 3 feet in height, but a wide base of 60 feet was secured for the remainder of the levee. In crossing some old drainage canals that had been cut for about 40 years, a decided difference was noted in the solidity of the material. Due to the small elevation of the surface along these canals they could furnish but very little drainage, yet in building levees across them it was noticed that they had affected the ground for a distance of several hundred feet, and that the levee could be raised in one layer to a height of about 6 feet above mean tide. This shows the advantage of allowing the first layer of material to drain for some time before placing the upper one. Most of the levee was brought to its present grade line with three layers of material, while in the soft portions it was necessary to place about five layers to bring it to grade. The levee at present seems to be holding to grade, and any further subsidence will be due to the decay of the vegetable material in the levee rather than to the spreading or subsidence of the base. Approximately twice as much material was excavated as will show in effective volume in the levee. The top width is at present about 4 feet, and the side slopes are 3 to 1. Thus far no seepage through this levee is apparent.

RESERVOIR CANALS.

This tract has a very complete set of reservoir and collecting canals. The sizes of the various canals were more or less proportioned to the amount of water that they would be expected to carry when draining the adjacent land and taking the water from the connecting canals. Thus practically the same degree of drainage should be secured in all parts of the entire district, and the loss of head when the pumps are in operation should be about as small as is practicable. The greatest length necessary for any ditch is about one-eighth of a mile. These canals alone should give the ground fairly good drainage, at least until the muck begins to decay and becomes more impervious than at present. The storage capacity of these canals when the water is lowered to a distance of 4 feet below the surface is about 0.75 inch; at a distance of 3 feet it would be 0.52 inch. It is intended to hold the water at the 3-foot level, and even at this level the reservoir capacity of this district will be as large as that in the average district where the capacity is all excavated. A depth of about 7 feet has been given the collecting canals, and as the larger canals are reached, near the pumping plant, a depth of about 10 feet is attained. Due to the great depth of muck these collecting canals finally will have to be deepened, for when 4 feet of muck has decayed the surface of the ground will be lowered perhaps $2\frac{1}{2}$ feet. This subsidence will, however, take a long term of years, and by that time the canals will have required cleaning several times, so that the increased depth of canal need not be made all at once.

These canals were all cut with a dredge of the hydraulic type. They are much more satisfactory than those cut with an ordinary dipper or orange-peel-bucket dredge, as they are left free from any soft mud and no great spoil bank is present on each side of the canal. In digging lateral ditches into these canals the expense of cutting through the spoil banks will be avoided and a considerable area of land usually wasted by being covered with excavated earth will be saved. The canals themselves should be more permanent, as the absence of a great weight on each bank will greatly decrease the tendency of the

material to flow into the canal. The surface is raised between 1 and 2 feet for a distance of 100 or 200 feet back from the canal banks by the deposit made by the hydraulic dredge. The cost of cutting the canals by this method is not as great as with the other type of dredge and the results are much more satisfactory. It is expected that in the future this type of dredge will be used almost exclusively where the ground is free from trees and stumps.

DITCHES.

The spacing of the ditches on this tract is 165 feet. With the canals at one-half the usual distance, and with a deep, porous muck soil, this spacing should give a sufficient amount of drainage for a number of years until the soil becomes more impervious, due to the decay of the vegetation it contains. Owing to the soft nature of the soil in this district a long time would have been required for it to become solid enough to use the ordinary type of apron traction ditcher. A capstan ditcher, or ditching plow, was therefore used to cut the ditches. The plow was pulled with cables running between two adjacent collecting canals. In each of the canals an engine with winding drum was mounted on a barge. After cutting a ditch the barges were floated along the canals to the location of the next one. In some of the softer portions this plow was found to be too heavy and plowed too deeply, so a lighter structure of wood was substituted which cut a very satisfactory surface ditch. This tract is free from logs and stumps, thus allowing the use of such machinery. When the surface has become fairly solid, due to the drainage afforded by these superficial ditches, the larger and heavier ditching plow can be used, and all of these ditches will be put down to a depth of 3 feet. By this method of ditching the time consumed in placing the tract under complete drainage will be considerably lessened, for a wait of several months would have been necessary before a traction ditcher could have been used.

PUMPING PLANT.

In location this plant is rather far to one corner of the tract, but due to the large size of the main reservoir canal no great loss of head should result in the canals when the pumps are in operation. The greatest distance that the water will travel in the canals to reach the pump is about 3 miles. The pumps discharge into the navigation canal that surrounds the district and connects with the bays and bayous to the rear.

The machinery consists of one 36-inch and one 24-inch cast-iron centrifugal pump direct connected to slide-valve engines. The boilers are of the return-tube type and oil is used as fuel. The discharge and intake pipes on both pumps are enlarged to save the usual loss of velocity head. The two units are mounted on separate concrete foundations, supported on piling, the foundation forming part of the dam across the outfall canal. The greater part of the dam is of mud held in place by the rows of sheet piling that form the cofferdam. This saves considerable expense for concrete and still insures a water-tight dam. It is planned to use the small unit in times of ordinary rainfall and to use both when necessary. The combined capacity of the pumps when operating at full load will be about 1.1 inches in depth in 24 hours. On account of the high tide to be expected in this vicinity, the pumps are capable of working against a 10-foot head. The capacity will of course be greatly reduced at this head.

The building over this machinery is of fireproof construction, being a framework of structural steel covered with heavy corrugated galvanized iron.

AREA NO 7, GUEYDAN, VERMILION PARISH, LA.

This district, containing 5,600 acres, is the first one being developed in a tract of some 90,000 acres lying in the southern portion of Vermilion Parish and bordering on the northern shore of White Lake. The general nature of the soil and other natural conditions have already been described. The elevation of the surface above mean tide level is between 2 and 4 feet and the slope of the surface is from north to south. This tract is a typical example of the higher and firmer prairies of this section as contrasted with those of the softer type immediately along the rivers of this part of the State. (See Pl. II, fig. 1.)

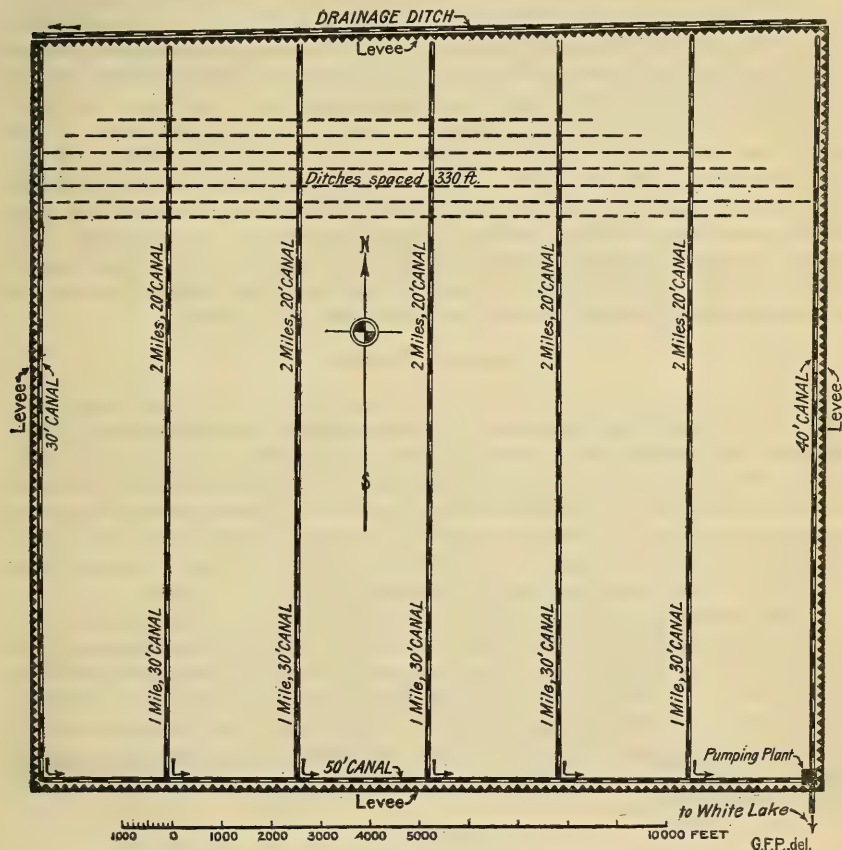


FIG. 15.—Sketch map of area No. 7, Gueydan, La., showing ditches and levees.

Work was begun on this district in June, 1911, and the pumping plant was started about March, 1912. Figure 15 shows the general arrangement of canals, levees, and ditches.

LEVEES.

Along the north side of this district a drainage canal had been cut some years previous to the beginning of the present work. A spoil bank of a cross-sectional area nearly sufficient to serve as a levee still exists on the south side of this canal. Along the other three sides the levee canals are on the inside of the district. In cutting a 25-foot canal 5 feet deep more than enough material

was secured to build a levee with a height of 5 feet and a top width of about the same. Owing to the solid nature of the subsoil, the levee as a whole subsides very little except for the usual shrinkage of the material itself. The slight depth of muck also contributes to this favorable condition. In a few places, however, some old muck-filled bayous have been encountered and the levee remaining after one trip over with the dredge is only about 2 feet high. It will be necessary to go over these spots several times to get the required height. The berms left by the dredges doing the work are not much over 8 feet. No muck ditch is being used under this levee. Taking into consideration the facts that the base of this levee is from 3 to 4 feet above mean tide, that the storm tide in this vicinity is not more than 2 feet, that the subsoil is very solid, and that the muck is only about 1 foot deep, it would seem in this case to be the best practice to place the levee canals on the inside of the district and thus to have use of them for drainage canals.

The levee should be certain protection from storm tides that occur in this section and should also cut off practically all seepage into the district. On the other hand, as all the canals are on the inside of the district their usefulness as navigation canals will be impaired. In the development of a district of this size the advantage of having navigable canals all around it is considerable. On newly reclaimed lands the question of water transportation is one of importance, as roads are very hard to construct when the land is first drained. It is the intention to use the levee as a road for most of its length.

RESERVOIR CANALS.

In addition to the canals that border this district a collecting canal has been cut every half mile throughout. These collecting canals are about 7 feet deep and the reservoir is of about the same depth at the upper end and 10 feet deep at the lower end. In this soil these canals should maintain their original depth and there should be no trouble from the flow of the earth when the canals are first pumped out. The canals are of ample cross section to insure a small loss of head when the pumps are in operation. When the water is lowered to a level 4 feet below the surface the storage capacity will be 0.75 inch.

A lock has been built at the end of the main reservoir so that barges can be floated into the district. The depth of 10 feet in the main reservoir will allow navigation even when the water is low enough to give drainage to the entire tract. This district has one of the largest excavated reservoir capacities of any of the districts so far attempted. The frequent and regular lateral canals make it an easy matter to install an efficient ditch system. Plate III, figure 1, shows a dipper dredge cutting reservoir canal and building levee on this district.

DITCHES.

Lateral ditches were cut on this district with an apron traction ditcher at a uniform spacing of 330 feet. (See Pl. III, fig. 2.) These machines worked on this district in from 1 to 3 feet of water. Owing to the solid nature of the soil the apron wheel did not sink into the ground to any great extent. Unlike the districts that are being reclaimed in the vicinity of New Orleans, the soil will not need to be drained for about two years before it becomes solid enough to cultivate in the ordinary manner, and this district should come under cultivation quite soon after the system is installed. However, the old muck-filled bayous will be soft for perhaps two years after the rest of the land is under cultivation. In these bayous the muck is about 5 feet deep. The area of this district that is in canals and ditches is about 3.2 per cent of the whole.

PUMPING PLANT.

This plant was located far in the corner of the district so as to place it directly on the main outlet canal to White Lake. If the plant had been placed in the middle of the south side the greatest distance that the water would travel to the pump could have been reduced from 6 miles to $4\frac{1}{2}$ miles. The length of outlet to White Lake would have been increased, however, so that the actual gain in decreased lift would have been very small.

There are two cast-iron centrifugal pumps, having diameters of discharge opening of 54 inches (fig. 16). The pumps have double intake pipes and both the intake and discharge pipes are tapered and enlarged to four times the area of the opening on the pump, and they discharge under water. These features cut the velocity head losses to about the smallest amount that would be economical. There are two engines of the Corliss type, having 16 by 36 inch cylinders; these are direct connected to the pumps. (See Pl. IV.) Return-

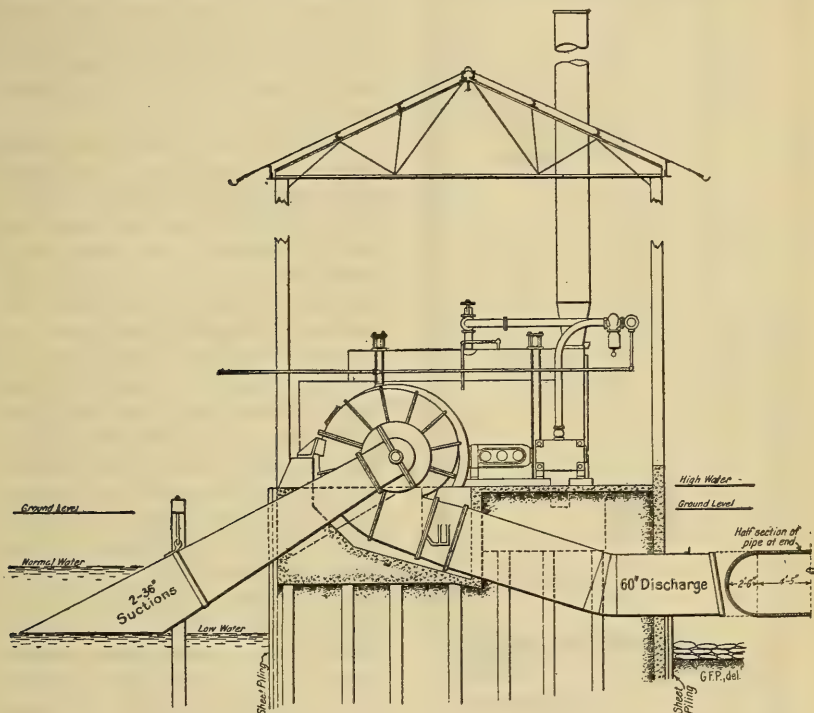


FIG. 16.—Elevation of pumping plant on area No. 7, Gueydan, La.

tube boilers are used, with oil as fuel. The machinery is mounted on a concrete foundation supported on piling. In driving these piling the subsoil was found to be very hard and the foundation should therefore be solid. When the plant is run at its full capacity the pumps will be able to remove about 1.50 inches of water from the 5,600 acres in 24 hours. By running the plant at an overload this rate can be increased a small amount. In case this proves to be a larger capacity than necessary an additional area of land will be brought into this district on the west side.

The building inclosing this machinery is a frame of structural steel, covered with heavy corrugated iron, and the plant is of fireproof construction throughout.

AREA NO. 8, NEW ORLEANS, LA.

This tract of land (fig. 17) lies within the city limits of New Orleans. It contains 1,085 acres. The district originally was a part of the swamp, and had

a heavy growth of several varieties of trees, although the predominating variety was cypress. There is a deep layer of muck on this tract, quite similar to the usual wet prairie muck, except that it contains a large percentage of leaves and twigs. Underneath this layer of muck is a subsoil of very sandy material that is quite porous. The growth of trees has been almost entirely cut, but as a whole the land is not cultivated and is allowed to grow up in weeds and brush. About 10 per cent of the area is now taken up by improved city lots.

The tract was inclosed by levees about five years ago. The levee along the canals was built a number of years earlier and the work was done by dredge. This levee has a width of from 20 to 40 feet on top, that part along the west side being used as a grade by the West End Railway, and that along the east side as a highway. The levee along Lake Pontchartrain was built with wheelbarrows, of a soil that is very porous and contains a high percentage of vegetable material, and as there is a canal quite close to the inside slope it is reasonably certain that the seepage is considerable. The fact that underlying this thick layer of muck there is a subsoil of porous sand would make seepage probable, not only under the small levee along the lake, but also under both wide levees along the canals. The interior drainage canals have been cut to the sizes shown in figure 17, and have been maintained nearly to their original size. Their average depths are from 6 to 8 feet. About 2 feet of water is kept in the canals to check the growth of vegetation.

No extensive system of lateral ditches has yet been constructed on this tract, only a few in the immediate vicinity of the improved section having been dug; these, however, drain but a small percentage of the total area. When the entire tract is well drained

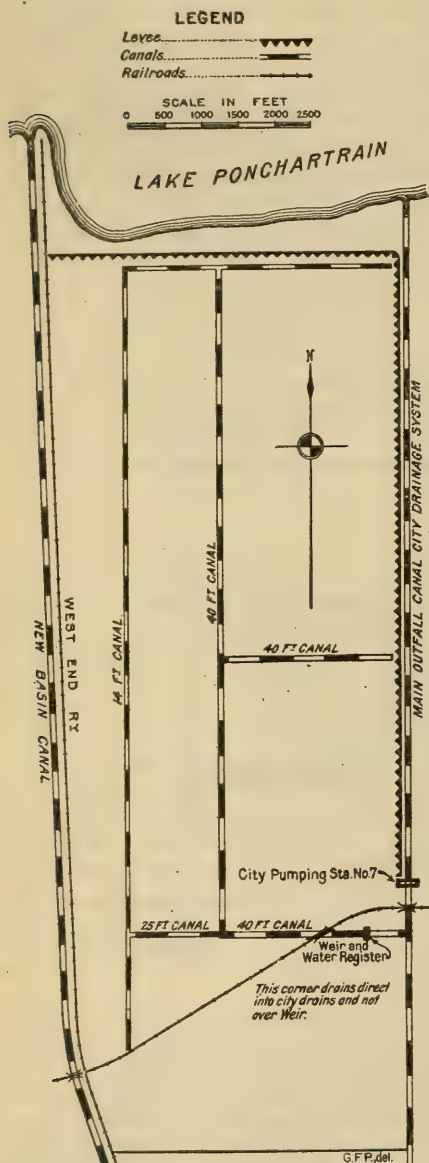


FIG. 17.—Sketch map of area No. 8, New Orleans, La., showing arrangement of ditches and levees.

Summary of natural conditions and drainage features on 12 reclamation districts in southern Louisiana.

Area No.	Parish.	Town.	Area.	Depth of muck.	Elevation above mean gulf.	Height of storm tide.	Height of levees.	Spacing of laterals.	Size of laterals.			Length of laterals.	Depth of water table.	Land in ditches.	Land in canals.	Reservoir capacity.	Pumping capacity in 24 hours.	Pumps.	Engines.	Boilers.	Fuel.	Work begun.	Date of first pumping.	Date of first cultivation.	Cultivated in 1912.	Remarks.
									Top.	Bottom.	Depth.															
			<i>Acres.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Inches.</i>	<i>Inches.</i>								<i>Per cent.</i>	
1	Jefferson.....	Waggaman....	2,600	0 -3	-2-9	None.	5	100 450	3	1½	3	2,400	1½	3.80	2.00	0.37	1.45	1 rotary..... 1 Minge, 42 by 16 inch..... 1 centrifugal, 36-inch..... Minge, 32 by 12 inch; 2½ by 8 inch.	1 vertical..... 2 slide valve horizontal..... Slide valve horizontal.....	2 water tube..... 1 return tube..... Return tube.....	Oil....	About 1898	About 1899	About 1900	100	
2	La Fourche.....	Lockport.....	647	0.5-2	-2-2	2	4	160	4	1½	3	5,280	2	3.30	.94	.45	1.11	2 Minge, 32 by 12 inch; 2½ by 8 inch.	Slide valve horizontal.....	Return tube.....	Oil....	1907	1908	1908	90	
3	do.....	Raceland.....	940	1 -2	0-3	2	4	200	4	1½	3	2,000	2	2.90	.47	.25	1.23	2 Minge, 32 by 12 inch..... 2 centrifugal, 30-inch.....	Slide valve..... Slide valve vertical.....	Locomotive..... Return tube.....	Coal.... Oil....	1907 1908	1908 1910	1909 1910	65 30	
5	do.....	Allemands.....	1,880	0 -1	0-2	2	4	210	4	1½	3	2,000	.....	2.60	1.00	.50	.95	2 centrifugal, 24-inch..... (Centrifugal, 24-inch, 36-inch.....	do..... Slide valve horizontal.....	do.....	Oil....	1910	Sept., 1911 Mar., 1912	1912	10	
6	St. Bernard.....	Poydras.....	2,500	4	0-1	6	7	165	4	1½	3	660	.....	3.30	1.50	.75	1.17	2 centrifugal, 54-inch..... 2 centrifugal, 30-inch, 3 48-inch.	Horizontal Corliss..... Cross compound condensing.	Water tube.....	Oil....	1910	1911 1912	1912 1912	None. 2	
7	Vermilion.....	Oueydan.....	5,600	0.5-1	1-4	2	5	330	4	1½	3	1,320	.....	1.70	1.80	.75	1.51	2 centrifugal, 36-inch..... 1 centrifugal, 15-inch, 1 18-inch.	Horizontal Corliss..... 2 gasoline, 40-horsepower	do.....	Oil....	1911	1912	1912	4	Plant partially installed.
9	St. Mary.....	Morgan City..	15,600	0 -1.5	1-6	4	6	330	4	1	3	1,320	.....	1.80	3.80	1.82	.87	2 centrifugal, 36-inch..... 1 centrifugal, 15-inch, 1 18-inch.	Horizontal Corliss..... 2 gasoline, 40-horsepower	Water tube.....	Oil....	1911	1912	1912	4	
10	St. Charles.....	Paradis.....	2,840	0 -2	0-3	2	4	330	4	1½	3	1,320	.....	1.50	.94	.45	1.40	2 centrifugal, 36-inch..... 1 centrifugal, 15-inch, 1 18-inch.	Slide valve horizontal..... 2 gasoline, 40-horsepower	Return tube.....	Oil....	Jan., 1910 1911	Aug., 1911 1911	 1911	None. 80	
11	La Fourche.....	La Rose.....	640	0 -3	0-3	3	4	210	4	1½	3	2,640	.....	2.90	.56	.27	1.30	2 centrifugal, 36-inch..... 1 centrifugal, 15-inch, 1 18-inch.	Slide valve vertical.....	Return tube.....	Oil....	1910	Sept., 1911	.....	None.	
12	do.....	do.....	2,560	0 -3	0-3	3	4	210	4	1½	3	1,320 2,640	.....	2.90	1.00	.48	1.50	2 centrifugal, 36-inch..... Centrifugal.....	Slide valve vertical.....	Return tube.....	Oil....	1910	Aug., 1912	.....	None.	Under construction.
13	do.....	Golden Meadows.	1,780	0 -2	0-2	5	6	200	4	1½	4	1,320	.....	2.80	1.25	.60	2.100	Centrifugal.....	Slide valve vertical.....	Return tube.....	Oil....	1910	Aug., 1912	.....	None.	Under construction.

1 Maximum.

2 As designed.

the run-off probably will be more rapid than at present. The drainage water discharges by gravity through the main outlet canal into the city drainage canal. The run-off from this tract is more natural than would be the case if a pumping plant were operated. To measure this discharge a 6-foot weir was installed in the outlet canal, and a continuous record of depth of flow secured by use of a special recording device.

RESULTS OF INVESTIGATION OF RECLAIMED TRACTS.

In the table facing this page is given a summary of all the details of reclamation and the prominent natural conditions on areas herein described, with corresponding data on a number of other districts. No detailed descriptions of these latter districts will be given, as conditions occurring on them are in general similar to those on the districts already described.

In explanation of this table the following notes are given:

In calculating the percentage of land that is in lateral ditches it was considered that for each ditch a strip 6 feet wide is lost to cultivation.

The reservoir capacity, in inches of depth over the whole area, includes the capacity of all canals between the general surface of land and the water level 4 feet below the surface.

The pumping plant capacity was based on a velocity of 12 feet per second through the discharge opening of the pump.

AREA.

The districts examined range in size from 640 acres up to 15,600 acres. The newer districts are nearly all among the larger-sized ones, the present tendency being toward larger districts. On some of the districts the shape and area were fixed according to the surrounding natural water channels, but most of them were fixed arbitrarily, as the surrounding marsh was level and unbroken by open water. With the increased size, the shape and boundaries of the districts will be more and more influenced by the topographic features of the marsh. So far, the districts have been rather small, as, owing to the limited capital available, it was necessary to get them under cultivation soon after the work was started.

SOIL.

The general nature of the soil in these tracts has already been discussed. In reclaiming the land no particular attention was paid to the character of the soil, except to the depth of muck overlying the silt. The figures given in the foregoing table show the range in depth of muck on the several tracts, the mean depth on these districts usually being an average of the two figures given. A considerable subsidence of the surface of the muck land takes place after drainage, this often amounting to as much as 75 per cent of the original depth of the muck. As pointed out in the description of area No. 1, the subsidence amounted to about $2\frac{1}{2}$ feet in 12 years of drainage. None of the other districts has as yet shown much subsidence, as they have not been drained or cultivated a sufficient length of time.

LEVEES.

The levees vary in height according to the storm tides that are encountered, although it is generally admitted that a height of about 4 feet is necessary to prevent seepage. Almost without exception the heights of the levees are sufficient to keep out the recorded high tides, although in the interior sections the fluctuation of water in the natural channels, due to rainfall, is greater than that caused by storm tides from the Gulf. The top width is usually from 5 to 10 feet. In many places levees are used as the main roads of the district; in

these cases the crown is somewhat over 10 feet. The maintaining of a road on a levee seems to aid in keeping out muskrats and other burrowing animals, but gradually decreases the height. The side slopes are usually quite flat, being about 3 to 1. In very few of the levees had any preparation been made for the base, either by clearing away vegetation or by cutting muck ditches. Where both the muck and subsoil were very soft, seepage through the base was not noticeable, but where the muck was turfy in character nearly all the levees developed seepage when the berm on the outside of the levee was submerged to any considerable depth. Seepage appears to increase in volume as the muck in the levee decays and shrinks; thus in some cases the older levees were not keeping out the water as well as they did at first. It has been necessary to cut muck ditches along many of these old levees to intercept the flow of water through their bases.

The majority of these levees were constructed with some form of dredge. The unit price for material, measured in excavation, was in the neighborhood of 7 or 8 cents per cubic yard, depending on the amount of timber and stumps encountered. It is always necessary to place more material in a levee than the final cross section indicates, owing to subsidence of the base and shrinkage of the material. This shrinkage will require from one and one-half to three times as much excavation as the final volume of the levee. The unit cost of levees will therefore vary from 12 to 25 cents per cubic yard, measured in settled embankment. If the levee is brought to a regular cross section by hand or machine work a small additional charge should be made; generally, however, the embankments are not surfaced after the dredge work is finished.

The natural growth of prairie grass soon covers the majority of the levees, and some of them have been sown to Bermuda grass. The levees are often pastured, and when this is done with care it affords an efficient and a profitable method of maintenance.

DITCHES.

The spacing of the ditches has been varied on the different districts according to the nature of the soil. Some of these are spaced too far apart to give adequate drainage, but, on the other hand, on none of the districts are the ditches too close together for economy; that is, the land is in no case over-drained. A spacing of 330 feet on newly reclaimed lands seems to be popular, with the idea of making the spacing 165 feet when the land becomes more impervious, due to the decay of the vegetable matter. The size of the ditches is quite uniform and is usually ample, except where the ditches are too long. The efficiency of these small ditches as water channels is very low, for they are usually partly filled with weeds and grasses. As most of the land is flat, flow is caused only by the piling up of drainage water in the ditch. A length of about a quarter of a mile has been found to give satisfaction in flat land, and when there is any considerable slope to the ground much longer ditches have been used with entire success. The use of the 6 to 8 foot collecting ditch to take the water from the laterals has not proved a success on the marsh-land districts, the maintenance charges being too great. The percentage of land taken up by these lateral systems is usually between 2 and 3 per cent. The cost of their excavation has been between 5 and 6 cents per cubic yard, and with a spacing of 330 feet the cost of the ditches per acre has been between \$2 and \$2.25.

GROUND WATER.

The ground water is controlled largely by the depth of the lateral ditches. Even though the subsoil be very fine grained and impervious, there is a considerable lateral movement of the water, as was shown by measurement of the

profiles of the ground water made on areas Nos. 1 and 2. (See figs. 5 and 8, pp. 26 and 31.) The slope of the ground-water profile is steep after a heavy precipitation and gradually flattens out after a few days of dry weather. Evaporation at the surface hastens this lowering of the water table, and measurements show that the profile of the ground water is usually much flatter in the summer months than in winter. In removing the ground water the effect of a ditch decreases toward the middle of the strip of land between the ditches, while the effect of evaporation is more or less uniform over all this strip of land, although it depends somewhat on the depth of water below the surface. The actual evaporation is greatest midway between the ditches, where the water is nearest to the surface. The variation between the summer and winter slopes of the ground-water profile is therefore due to the difference between the combined effect of the ditch and evaporation in summer and the effect of the ditch alone in winter, as evaporation is then comparatively very slight.

After long periods of small precipitation and high temperature the water is often lowered by evaporation below the bottom of the ditch, but at these times the ground water is nearly level, as the effect of the ditch is then almost entirely eliminated. It was also noted that the ground water was reduced to lower levels by evaporation in the fine-grained silt soils than in the coarser muck soils.

RESERVOIR CANALS.

The reservoir capacity is as variable as the size of the district. No attempt seems to have been made in the earlier districts to provide reservoir capacity, all ditches being constructed as drainage channels. Even this feature was not sufficiently provided for in the earlier districts, as the canals were not of sufficient cross section to bring the water to the pumping plant rapidly enough to secure continuous operation. The resulting large slope of the water surface in the canal and the consequent loss of head acted directly on the pumping plant to increase the lift. The present tendency is toward increased storage capacity, with deeper and wider canals. The loss of head during the operation of the pumps is thus partly overcome, and in addition the plant is not required to operate so intermittently. Some of the smaller canals on the older and smaller tracts are so shallow as to allow vegetation to grow on the bottom, and, moreover, the small deposit of mud from lateral ditches fills the bottoms of the canals above low-water line and thus checks the flow. With a greater depth a small deposit of silt would not have such great influence on the efficiency of the canals and vegetation would not grow so readily on the bottom. In many of the new districts the slope of the water surface in the main reservoir is calculated to be as low as two-tenths of a foot per mile when the pumps are operating at full capacity. However, this slope increases as the water lowers and the cross-sectional area of flow decreases. It has been observed that the larger reservoir capacity takes care of the smaller rains and that the pumps therefore do not need to be started for them; it also appears that at times of heavy precipitation the reservoir takes a part of the run-off and decreases the amount of water that must be removed at once by the pumps. It is a notable fact that the largest district has the largest reservoir capacity. This is due to the fact that a number of large and deep natural water channels were included in the district. It is the only one of the enumerated districts where such a feature had been included in the drainage plans.

The maintenance of reservoir canals in these soils for the first few years has proved to be quite an item. When the water is first lowered it must be done very slowly and with great care to prevent caving of the banks and general shrinking of the cross section of the canals. A deposit of silt will occur, and

in many cases it has been found necessary to redredge the canal about three years after construction. The surrounding land is then solid enough approximately to hold its place and to make the canal permanent. Canals constructed with a hydraulic dredge are better cleared of soft mud at the time of construction, and, due to absence of heavy spoil banks close to the edge of the canal, appear to hold their original size more satisfactorily than those constructed by other forms of dredge.

On the newer districts the area in canals is about 1 per cent of the area included within the levees. The average cost per cubic yard for cutting internal canals is between 6 and 8 cents, the higher figure being applicable to cases where the ground is covered with a growth of timber, when the work is done with a dipper dredge. If the land be free from stumps and sunken timber the work can be done either by dipper dredge or hydraulic dredge for about 6 cents per cubic yard.

PUMPING PLANTS.

The theoretical normal capacity of the plants examined averages 1.22 inches in depth of water over the whole area removed in 24 hours of continuous operation. On most of the districts the normal capacity can be increased somewhat by speeding up the machinery. The reservoir capacity and pumping-plant capacity are not proportioned to each other at all uniformly. There is such a wide variation in this regard that either some pumping plants are too large to be economical, or a number of the others are far too small to give drainage. As little flooding of any of these districts has occurred, it would appear that the former is true. There is as much variation in capacity in the newer plants as in the older ones. No settled policy as to required capacity has been established. Some plants have been built of ample size, so that if it became apparent that more water could safely be handled an addition could be made to the area drained. In the summary (facing p. 53) it will be noted that the smallest pumping-plant capacity appears on the largest district, which district has the largest reservoir capacity. Even the smaller plants have their pumping capacity divided between at least two units. This allows the use of part of the plant during low-water flow, with as small capacity as is desired. In some of the plants which consist of two duplicate units each unit is nearly large enough to take care of all the water; this provides a reserve capacity in case of breakage of one of the units.

The static lift in these pumping plants varies from 3 to 10 feet. The bulk of the water usually is lifted only about 3 feet, the lift increasing as the water in the canal is lowered, so that it is only during the last few hours of pumping that the lift approaches the larger figure given.

The cast-iron centrifugal pumps are largely used and have been found very much more satisfactory than the older types of vertical wooden-case centrifugal pumps. While the first cost of the latter type is less than that of the cast-iron pump the efficiency also is less, and the maintenance much greater. As pumps of the vertical wooden-case type can not be direct connected to engines they are not so reliable in operation, and as they do not discharge into a closed pipe no siphon effect can be arranged, and their actual lift usually is from 2 to 3 feet greater than the effective lift. Also they do not lend themselves well to installation on a concrete foundation.

Only one rotary-pump installation was examined, and while the pump operates very satisfactorily it was lifting the water fully twice the necessary height. Rotary pumps of the desired capacity are adapted to a minimum lift of about 10 feet, and as the usual lift is about half this amount the loss of energy is far too large. All the modern plants are equipped with horizontal

cast-iron centrifugal pumps, this type having proved to be very reliable. Continuous runs of 140 hours have been made without trouble.

On most of the pumps the suction and discharge piping has been so arranged that the friction losses are small, and the areas of intake and discharge openings of the pipes have been enlarged to decrease velocity head losses. On some plants this velocity head loss often amounts to 4 feet, and as a result the plant does nearly twice the amount of work necessary. The piping of the centrifugal pump on area No. 1 and on two pumps on area No. 11 is not enlarged or tapered, and there are large losses due to this defect. All of the more modern pumps have large intake and discharge openings, and the pipes often are tapered the full length. When the suction ends of the intake pipes are cut vertically whirlpools will develop over the pipes and air will be admitted, even when the water is 2 feet deep over the pipes. If these pipes be cut horizontally the water can be lowered to within an inch of the ends of the pipes before air enters.

On the smaller and older districts simple and reliable engines have been used, but most of them have a very large steam consumption. Reliability and low first cost have been sought, but, due to low-class labor, many of these plants have had frequent breakdowns and large repair charges. A few of the large districts are installing high-class machinery, and one, as shown in the summary, has installed cross-compound condensing engines and water-tube boilers. Gasoline engines have been used on one small plant only, and although fairly satisfactory no general use of them is expected.

Owing to the mild nature of the climate very few of the plants have been inclosed in permanent structures. Timber frame structures covered with heavy corrugated galvanized iron are very common among the plants, and while these are quite durable the danger from fire is very great. Two plants of this type have recently burned.

The cost of such plants as those described ranges from \$4 to \$7 per acre of the district drained, according to the type and the capacity of the machinery.

VEGETATION AND DEPTH OF DRAINAGE.

As noted in the general description of this section, most of this land, whether salt or fresh-water marsh, is covered with a heavy growth of grass (see Pl. II, fig. 1). This seems to thrive even if the land is continuously submerged with a small depth of water. However, when the land is drained sufficiently to remove the water from the surface this grass grows much more luxuriantly, and has been cut for hay two to four times in a single season. It appears to grow better with deeper drainage. When cut for hay it makes excellent feed for stock, and is much in favor with all the local planters who have given it a feeding test. Deeper drainage is required for cane and corn, although fair crops of corn have been grown with only about one foot of drainage. It would appear that good crops can be grown if the water is held down to 2 feet below the surface, but all planters are of the opinion that the deeper the drainage the better, down to a depth of $3\frac{1}{2}$ feet. The truck crops all require complete and early drainage, but not necessarily as deep as that required for cane and corn. As droughts are of rare occurrence, not much trouble has been experienced in getting the ground water too low in the soil. By proper management of the pumping plant the stage of water in the canals and ditches can be so arranged that the water will not be reduced too great a distance below the surface. This artificial control of the water content of the soil is of decided advantage, and it should make these lands as independent of natural conditions as are the irrigated lands of the West. Crops on the muck lands seem to withstand

drought better than those on the older sandy-land plantations, as the muck is more retentive of moisture.

TREATMENT OF LAND AND CROPS.

In general the water was lowered as rapidly as possible on these marshlands when they were first reclaimed. The lateral ditches were then constructed and complete drainage of the soil obtained. No trouble has been experienced from too rapid drainage. Although the muck often is covered with a very tough sod, and is itself often turfy in character, it is full of muskrat holes, and as it dries and shrinks during drainage a great number of cracks open that reach to the underlying soft mud. This has made it impossible in a great many cases to do the first work of plowing with ordinary farm animals and machinery. The land usually is plowed the first time with a set of gang plows drawn by some form of mechanical tractor. (See Pl. II, fig. 2.) It is necessary that the tractor be mounted on very wide wheels, and the substitution of apron traction for wheels has been made very successfully. Plowing has been done with these tractors on land that is too soft to bear farm animals. The heavy growth of prairie grass must first be removed. Usually the first plowing is done in the winter months when the grass can be burned off closely. A set of gang plows fastened to a frame hinged directly to the tractor frame has worked most successfully. After one thorough plowing of the ground with a gang plow the holes and cracks are so completely filled that ordinarily no trouble is thereafter experienced in using farm animals if the tract has been well drained during this period. It is very essential during the first few years of drainage that the water table be held at a good depth to allow the soft subsoil to solidify. This involves deep winter drainage, as well as during the growing season.

Usually the first crop planted is corn, and it is frequently drilled in by a separate drill attachment at the time of the first plowing. Sometimes this first crop makes a yield of 30 bushels to the acre without further cultivation. One plowing, however, does not kill the original growth of prairie grass. In fact, if the ground is once plowed the growth of prairie grass the next year will be more uniform and luxuriant than it was before. Intensive cultivation for the first few years is necessary, although in growing cane and corn no trouble is experienced after the crop has reached a height of 3 or 4 feet. As truck crops usually are cultivated very intensively, no great trouble is experienced in keeping down the growth of grass. After the growth of the first crop of corn the land is replanted to corn, cane, or truck crops. The soil seems to be suitable for almost any kind of truck, and excellent yields are harvested. Some 40 to 60 bushels of corn to the acre have been successfully grown, and the yield of cane varies from 25 to 40 tons to the acre.

Where the original surface of the soil was covered with a growth of cypress timber a large additional expense must be incurred in bringing the land into cultivation. The expense of clearing cypress land ranges from \$30 to as high as \$100 an acre, depending on the character of the growth. In certain sections of the prairie lands a very heavy growth of submerged stumps is found, and after the land has been drained for a year or two the shrinkage of the muck soil will bring these stumps to the surface. They will then interfere with cultivation very greatly and necessitate a large expenditure for removal.

FINANCIAL.

In its original state much of the prairie land is worthless, its only usefulness being in that it serves as a trapping and hunting ground. Its present market

value is due to possibilities of reclamation rather than to any present usefulness and is more or less speculative. The value of the land varies according to the completeness and permanence of the drainage improvements, as well as according to its original character. A wide variation in the quality of the improvements exists, especially in the pumping-plant equipment. The cost per acre of reclaiming the various districts depends on natural conditions, the completeness of reclamation, and the character of the drainage improvements. The usual variation in the cost of such reclamation is from \$25 to \$35 per acre.

SUCCESS OF DRAINAGE.

The drainage of these lands has been uniformly successful, and from the drainage engineer's standpoint the work is past the experimental stage. Where successful drainage has not been attained it has been due to insufficient and poorly constructed improvement rather than to inherent and insurmountable difficulties. Some districts have been drained without the advice and services of an engineer, and while in some such cases successful drainage has been secured, it was not secured with the greatest economy, the proposition that if enough money be spent the land can be drained being a self-evident one.

The usual faults in the drainage systems are—

- (1) Poorly constructed and leaky levees.
- (2) Poorly constructed and inefficient pumping plants.
- (3) The lack of sufficient canal capacity to drain successfully the interior of the tract.

INVESTIGATIONS TO BE MADE BEFORE RECLAMATION.

Before attempting to reclaim any district of marshland, the following points should be thoroughly investigated:

- (1) The depth and character of the muck.
- (2) The character of the underlying silt.
- (3) The elevation of the land above ordinary stages of water in the surrounding lakes and bayous.
- (4) The ordinary and extreme variations of water level in these lakes and bayous.
- (5) The elevation of the ordinary and maximum storm tides.
- (6) The existence of sunken timber and stumps.
- (7) Transportation facilities.

In addition to the above, the topographic features of each district should be investigated in detail by a careful field survey and a complete and definite plan worked out by a competent engineer. The work should then be constructed under competent supervision and should be of a permanent nature, since the need for the improvements will be permanent.

FACTORS AFFECTING DRAINAGE BY PUMPING IN SOUTHERN LOUISIANA.

While the feasibility of reclaiming these wet lands has been demonstrated beyond question, there are a number of details of practice that have not yet been satisfactorily worked out, and it is not possible at this time definitely to recommend a line of procedure that will result in the most efficient and economical drainage of any tract of wet prairie land. In the following pages are discussed briefly each of the important items that enter into this form of reclamation. The conclusions presented are necessarily based upon a study of a rather limited practice, and further experimentation and investigation may alter somewhat certain of the recommendations herein made.

AREA OF THE DISTRICT.

Although in many localities topography has a large influence in fixing the area of a reclamation district, there are many large bodies of land of such a character that the size of the unit would be determined almost entirely independently of topographic conditions. In order to make clear the conditions governing the determination of the most desirable size of unit, the respective advantages of the small and large districts will be enumerated. The principal advantages of the small unit are:

- (1) Short internal drainage canals with small losses of head and the consequent low lift.
- (2) Short haul to outside water transportation.
- (3) Small area affected in case of failure of protection levee.
- (4) Small capital involved.
- (5) Short time required to place land under cultivation and early realization on investment.

The advantages of the large district over the small one are:

- (1) Low cost of levees per acre of protected land.
- (2) Possibility of using natural ridges in part for levees.
- (3) Possibility of using natural bayous and lakes as part of the interior drainage system.
- (4) Use of efficient machinery due to more continuous operation of the pumping plant.
- (5) Low first cost, per unit of area, of pumping plant due to centralization of equipment and smaller relative capacity.
- (6) Low unit operating charges on pumping plant.

The benefit of low lifts on the smaller districts is offset by the advantages in using more efficient machinery for the high lifts on larger districts and the less cost per acre of machinery. Unit labor charges for plant operation also would be much less on the larger districts. Although the haul to water transportation on large districts would necessarily be greater, with larger interests involved good roads could be economically built and maintained. Since the cost of the levee per acre of reclaimed land would be much less on a larger district, a better class of levee could be constructed and breaks prevented. While at times the small district could perhaps take advantage of natural ridges, this would usually result in too much irregularity in shape and only in rare cases could the small district include natural bayous or lakes as reservoirs. The advantages, in the case of the small district, of the small capital involved and the earlier return on investment might easily be offset by the increased cost per acre of construction of levees, canals, and pumping plant. Just what is the most economical size of district has not yet been determined; it is a matter that would be greatly affected by local conditions. However, it is the consensus of opinion among engineers engaged in this work that districts containing less than 2,000 acres are not at all desirable. Most of the districts now being planned are several times larger than this. One of the newest districts, and the largest yet planned, lies just across the Mississippi River from the city of New Orleans and contains 37,750 acres.

LEVEES.

The location of a levee influences its design, construction, maintenance, and usefulness to the district. Unlike levees along our rivers, those along the average reclamation district in this section have not been located according to the topographic conditions, but rather according to property or land lines. This has usually resulted in regularly shaped districts and minimum length of

levee for area inclosed, but the cost of construction and maintenance per unit of length has often been much greater than it would have been if some attention had been paid to topography. Throughout most of the wet prairie there are winding bayous that have along them solid ridges of silt that average from $1\frac{1}{2}$ to 2 feet above general ground surface. In other places the bayous are entirely filled in and there have been left ridges of silt having widths of from 200 to perhaps 1,200 feet, with the usual elevation of 2 feet. On small districts it is usually impracticable to take advantage of these ridges to any great extent, as to do so would make the shape of the district too irregular, but on larger districts the straighter ridges can be chosen, as irregularity of outline is not so large an item. If the levee is located on a solid ridge the material will be more stable and impervious and the levee can be made of less cross-sectional area than would be necessary if it were located in the soft prairie. Construction will also be easier and cheaper and the expense of maintenance will be much less.

The design of the levee will depend largely on the local conditions. Its top should be above storm tides and the highest stages of water in surrounding lakes and bayous from 1 to 3 feet, depending on the size of the district and the probability of previous high-water marks being exceeded. A minimum height of about 4 feet should be used through the soft prairie section, as anything less is not likely to prevent seepage satisfactorily, for when located on a ridge the water will stand against a levee only for short periods, while if located in a soft prairie the water will be in continuous contact with the lower foot or two of the levee. In places exposed to strong wave action the height should be sufficient to provide for the break of the waves; in addition, some provision should be made for protecting the levees from the erosive action of the waves. This protection might well be secured by planting willows some distance in front of the levee.

Where the levee is located on a ridge the top width may safely be made 4 feet, with side slopes 2 to 1. A levee of this type is often built with wheelbarrows, and although the unit cost for this method is quite high, being about 18 cents per cubic yard, the total cost is considerably less than it would be if the work were done with the usual floating dredge. Yard for yard the dredge would, of course, handle the material much the cheaper, but the excavation would be more than would be necessary for the levee. This objection would be overcome if the dredge were building a levee along the bank of a bayou of sufficient depth to float the machine, or if a reservoir canal were being excavated within the district, the waste bank to be used as a levee.

Where the levee is located in the soft prairie the top width should average about 6 feet. The side slopes should be about 3 to 1; in fact, if the material is very soft it will not take a much steeper slope than this during construction. As the material always becomes more stable after being placed in the levee, no trouble should be expected from slides after it begins to dry in place. The berm along the base of the levee should be at least 10 feet. Where the soil is exceptionally soft this should be made as much larger as practicable, at least 15 feet, and it will be better if conditions permit its being made 20. The width of berm will, of course, depend somewhat upon the nature of the machinery used in construction. Where the levee canal is on the inside of a district, special effort should be made to leave a wide berm.

Some type of floating dredge should be used in the construction of most levees. In heavily timbered sections, or where old submerged stumps are numerous, the dipper dredge will work to the best advantage, but in the open, grass-covered prairie the orange-peel-bucket dredge has many advantages. Owing to the longer boom and narrower hull, the latter type of dredge is able

to leave a wider berm along the toe of the levee. It is also better able to sort the material placed in the base of the levee, for the top layer of muck can first be taken out of the canal, and then the silt underneath, while the dipper dredge usually will cut up through both the silt and the muck and thus mix them. The levee should usually be constructed in several layers, for both the base and the material are likely to be so soft that subsidence will be too great if a height of more than a few feet is attempted. This yielding of the base often will cause the side of the canal to cave, especially if the berm be small.

The total subsidence and shrinkage of levees in this section often amounts to 50 per cent, and in special cases is as great as 80 per cent. Practically all of the subsidence and a part of the shrinkage takes place during construction, so that the remaining change in height can be taken care of by maintenance. When a large percentage of muck is placed in the levee the shrinkage will be great for a number of years, due to the decay of the vegetable material in the muck.

For placing several layers in a levee the orange-peel bucket is especially suitable. After a canal is once cut in the soft prairie there will be a considerable depth of soft mud in the bottom that makes very poor levee material.

The dipper dredge, when working in such a canal, will place a large percentage of such soft mud in the levee, while an orange-peel bucket, when dropped forcibly, will penetrate the undisturbed silt below and fill with it, the soft mud running off when the bucket is raised.

If the site of the levee is along a solid ridge above ordinary water level, no special precautions need be taken to prevent seepage, although all stumps and logs should be removed from the site, and a shallow ditch should be cut to insure a perfect bond between the ridge and the levee. On the other hand, if the levee is through very soft prairie, the material dropped from the dredge will penetrate the muck and form a good bond with the underlying silt. It is on the portions where the muck is thick and turfy in character that particular pains must be taken. A ditch cut along the center line of the levee before the dredge starts working is of no special benefit, as the material placed back in the ditch by the dredge will be largely muck; however, this treatment will break the continuity of the muck and help to cut off a portion of the seepage. A better plan is to wait until the first layer of material has been placed by the dredge and then to cut a ditch along the toe of the slope of the levee opposite to the dredge and to refill it with impervious silt dredged from the bottom of the canal. This will insure a good bonding of the material and is a necessary part of the construction. At times old muck-filled bayous will be encountered which must be closed with levees. In such cases the quickest, and quite often the cheapest, way to insure that the levee will hold its grade line is to drive two rows of sheet piling across the bayou at the proper spacing. These rows should be tied together with rods and the fill made between them.

After the soft material in the levee has dried sufficiently it should be smoothed off and brought to grade. Usually the natural growth of prairie grass will soon cover the levee, but Bermuda grass makes better sod for maintenance purposes. Careful grazing of the levee saves cutting the grass and gives partial protection from burrowing animals. After the levees are once constructed, very little maintenance is required to afford permanent protection from all overflows that do not actually overtop them.

INTERIOR DITCH SYSTEM.

Rainfall and seepage cause an accumulation of water within the levee district that must be collected by a system of ditches and canals, led to a central point,

and discharged over the levee by means of pumps. These internal water courses usually consist of lateral ditches which collect the water from the fields, and reservoir canals which receive the water from the laterals and carry it to the pumping plant.

LATERAL DITCHES.

On the typical wet prairie reclamation district the land is so nearly level that a regular layout of ditches is desirable rather than a location designed with a view to taking advantage of such slight surface slopes as may exist. The ditches should be cut in parallel lines and at such a spacing as will correspond to the character of the land. In the newly reclaimed land that has a deep layer of muck, ditches spaced 330 feet apart should give sufficient outlet both for surface and underdrainage, and after some years of cultivation, when the soil has become more impervious, intermediate ditches can be cut, making the spacing 165 feet. This divides the land into 5 and 10 acre tracts when the ditches are constructed in the usual lengths of one-fourth and one-half mile, respectively. Ditches with 4-foot tops, 1½-foot bottoms, and depths of 4 feet should give sufficient capacity unless they are too long or become badly choked with weeds and grass. In practice on drainage districts in this section it has been found that in flat land such ditches can be made one-fourth mile long with good results, and they have in a few cases worked fairly well at a length of one-half mile. However, this greater length is not recommended, as the ditch must be maintained in almost perfect condition in order to give satisfactory drainage. Such ditches can be cut by hand labor for about 5 or 7 cents per cubic yard.

Traction ditchers which will operate on soft prairies have been in use for some time and will compete with hand-labor prices and cut about the same class of ditch; however, where there is much sunken timber or stumps the work must be done by hand. On the softer prairies these traction ditchers can not be used until some months after the tract has been drained and the land has become somewhat solid. Ditches can be cut with a heavy wooden-framed plow, especially built for the purpose, drawn across the strips of land between the reservoir canals by cables and pulling engines mounted on barges. Ditches can be cut in this manner as soon as the water is off the surface, and thus the bringing of the land under cultivation will be hastened by several months. Field ditches on this class of land require a great deal of attention for the first few years after cutting to keep them serviceable. A soft semifluid mud gradually fills the ditches and water-loving grasses grow very rapidly. Where ditches have been cut with a plow they can readily be cleaned by drawing the plow through them. This method, however, will deposit most of the mud in the reservoir canal and will eventually reduce the area of the latter very materially.

Practice in this section has shown that to keep such ditches in a serviceable condition the grass and weeds should be cut out of them two or three times a year, and that every two years about 1 cubic foot of material per linear foot of ditch must be excavated. The total yearly cost, including interest on first cost, maintenance, and rental of land consumed in ditch, is about 55 cents per 100 feet of ditch, or \$1.40 per acre for a spacing of 165 feet. In the firmer and more open soils tile might well be used to replace a considerable number of the ditches. The interest on the cost of such tile drains would amount to 30 cents per year for each 100-feet of drain; no maintenance or rental of land consumed should be charged. For a spacing of 165 feet this would make a charge of 80 cents per acre per year, or would be an annual saving of 60 cents per acre over open-ditch drainage. The action of efficient tile drains would also be more uniform. In the case of the ditch, during the time immediately before

it is cleaned out, the drainage secured is comparatively poor. The land would not be so badly cut up if tile were used, and the necessity for a great number of small bridges would thus be removed.

RESERVOIR CANALS.

The primary requisite of reservoir canals is that they give sufficient outlet to the lateral ditches. To do this they must be spaced not more than one-half mile apart and usually they should be located in parallel lines. In building the levee around a district the resulting canal can sometimes safely be made on the inside of the levee and consequently used as a reservoir canal. On small districts this canal may be extensive enough to make up the entire reservoir-canal system. The practice of placing the levee canal inside the district has proved either a success or a failure, according to local conditions. If the berm between the levee and canal is wide, if the base is above ordinary stages of outside water, if there is no canal immediately outside the levee, and if the storm tide is low, such construction should not result in any great amount of seepage or subject the district to any danger from storm tide. On the other hand, if the canal is placed outside the district the seepage will be less, the levee will be safer in time of storm tide, and the canal can be used for navigation purposes. In all but the most favorable locations present practice tends toward placing the levee canal outside the district and cutting an interior system of reservoir canals.

The reservoir canal should be of such depth and cross section that the water will ordinarily be held at least 4 feet below the surface, although immediately after heavy precipitation the water may safely stand at the level of the lowest land for several hours. The reservoir canal serves a twofold purpose: (1) To take the water from the lateral ditches and carry it to the pumping plant, and (2) to store up the dry-weather flow of the ditches, so that the pumping plant will not need to be operated so frequently. Canals designed with only the first consideration in mind are smaller than when any considerable reservoir capacity is desired. If, however, the canals are correctly designed for storage capacity the question of flow will be taken care of. When heavy rains occur the storage capacity in the canals will take part of the run-off and temporarily relieve the pumping plant. Thus by an increase of reservoir capacity a less capacity of pumping plant will be required, and the plant can be operated more economically. The relative capacities of reservoir canal and pumping plant should be such that the interest and depreciation on the two investments, plus the cost of operation, would be a minimum. A complete set of records maintained on a number of typical reclamation districts for several years will be necessary before a relation can be established that would be capable of general application.

In some of the districts already constructed the reservoir capacity is about 0.6 inch in depth of water over the whole area. In these the average slope of the water surface in the canals is theoretically less than 0.2 foot per mile, with an average depth of flow of 6 feet and a run-off of 1 inch per day. If the reservoir capacity is so proportioned that the velocity of flow is nearly uniform in all parts of the system, the slopes can be held very close to the above figure. These slopes will of course increase when the water is lowered to near the bottom of the canals, but as the bulk of the water will be pumped at the time when the canals are full this increase of slope is not especially objectionable.

The local conditions will decide to some extent the question of using broad, shallow canals or deep, narrow ones. A broad, shallow canal has more of its

cross section available for storage, but after the water is reduced to 4 feet below the surface the slopes will greatly increase and trouble may be encountered in taking the water from the distant portion of the district. A minimum depth of about 7 feet seems to prove desirable in practice. This prevents vegetation from growing in the bottom of the canals and considerable silt deposits can be stored, so that the canals will not so frequently need to be cleaned. The canal should be gradually deepened as it nears the pumping plant to provide for the slope and consequent lowering of the water surface.

If the material taken from the reservoir canals is not to be used for levee construction and the land is free from timber and stumps, a hydraulic dredge is the most satisfactory means of cutting them. The unit price will then be lower on canals of a section exceeding 7 by 25 feet than if the work be done with another type of dredge and the canal will be better cleaned out and more permanent. Side slopes can be cut as desired with the hydraulic dredge and the material is deposited in a thin layer rather than in a high spoil bank. If the work is done in heavy timber a dipper dredge must be used, but if the growth is light either a dipper or an orange-peel-bucket dredge can be employed with the advantage in favor of the latter.

During the first few years after construction the maintenance charges on reservoir canals are quite high. A certain amount of bank caving occurs and a large amount of semifluid mud enters through the lateral ditches. The velocities of flow in the canals are not sufficient to transport any great amount of this material to the pumping plant. After the district is once thoroughly drained and cultivated the soil becomes more firm and very little material is then carried by the lateral ditches, as the average velocities of flow in them are very small. The canals can then be cleaned very satisfactorily with a small hydraulic dredge, as the material to be removed will usually be too soft for the dipper type of dredge.

PUMPING PLANT.

The drainage of low-lying wet lands by means of pumps has been described in a former publication of this office.¹ This publication discusses the general character of land drainage by means of pumps and deals especially with conditions in the upper Mississippi Valley. It is recommended that the reader obtain the above-mentioned bulletin. The general nature of this method of draining in southern Louisiana is much the same as described in this bulletin, but there are many differences in detail that deserve mention. These differences chiefly affect the capacity and operation of the pumping plant.

NECESSARY CAPACITY OF PLANT.

The general method of operation of plant in this part of the country is far different from that in the northern latitude, so, before discussing in detail such rainfall and run-off records as are available, it might be well to describe the usual method of operation.

In this latitude farming operations are conducted every month in the year. While general field crops are growing only about 9 or 10 months, the field must be kept sufficiently well drained to admit of cultivation at any time. The bulk of the heavy plowing is done during what are ordinarily called the winter months. The need of the pumps is therefore more or less continuous; that is,

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 243.

the run-off at any time of the year must be taken out promptly. The influence of evaporation at different seasons of the year causes a great variation in the manner of operating the pumps. A heavy rainfall in summer necessitates continuous operation of the pumps for a period sufficient to empty the canals and ditches. The water that will continue to run out of the lateral ditches will often be more than balanced by the evaporation, so that it will not again be necessary to start the plant until another period of heavy precipitation occurs. Small local rains in summer will in all likelihood pass unnoticed. During the winter months a heavy precipitation necessitates a relatively longer period of pumping than in summer. Two or three days after the canals have been emptied the ground-water drainage entering through the lateral ditches will, owing to lack of evaporation, make it necessary to operate the plant for a few hours, and after an interval of about 10 days it will again be necessary to do some pumping, although no precipitation may have occurred during the intervening periods. If the reservoir capacity of the canals be small the operation of the pumping plant will be still more intermittent. If the plant is divided into two or more units, one unit only may be operated for the dry-weather run-off. The total time of pump operation during the year rarely exceeds 45 days of 24 hours each and often drops to as low as 15 days. The total number of days on which the pumps are operated average about 70.

In southern Louisiana most of the pumping plants so far installed have a theoretical capacity of at least 1 inch and many of them $1\frac{1}{2}$ inches in depth of water over the inclosed area in 24 hours. The 1-inch run-off is equivalent to approximately 27 second-feet per square mile of area, or 0.042 second-foot per acre.

The necessary capacity of a pumping plant depends on the size and slope of the district to be drained, the depth and nature of the muck, the available storage capacity of canals and ditches, the system of lateral drains used, the method of operation of the plant, the character of the crops raised, and the amount and distribution of the rainfall. The proper allowance to be made for each of these factors can only be determined as the result of careful and complete observations in the field. Not only should the results for each district examined be carefully worked out, but the investigations should include a sufficiently large number of typical districts and should continue for such a length of time as to make the results of general application. Some of the above factors have been quite closely investigated over a few districts and all of them have been covered in a general way. While the results obtained are not final, the investigations still being carried on, these details will be discussed in the light of such investigations as have been made.

In planning gravity drainage districts it is customary gradually to decrease the run-off coefficient as the size of the district increases. With one exception the variation in size of the district in this section is as yet not great; therefore not much attention need be given this feature. In the summer, when rains are almost purely local, the larger district is not so likely to receive rains over its whole surface as is the smaller district. However, the rains that most heavily tax the pumping plant occur in the spring of the year and are general in character.

The variation in surface elevation on the average district is usually slight, but where the district fronts on a ridge having an elevation above the prairie land of from 8 to 12 feet it has been noticed that the lower lands become flooded and that the required capacity of pumping plant is nearly 50 per cent greater than on the flat lands. This flooding of the lower lands can be partly

overcome by a corresponding design of the various parts of the collecting system. By careful location of gravity outlet ditches this drainage water from the higher lands can in some cases be entirely diverted.

The character and depth of the layer of muck overlying the subsoil on these lands have a large influence on the run-off. The muck absorbs water very readily and if well drained to a depth of 3 feet its storage capacity is about 8 inches. When the land is first drained this muck will absorb water nearly as fast as the heaviest rate of precipitation, but as it decays and compacts both the storage capacity and the rate of absorption decrease very rapidly. A gradual increase in the rate of run-off must then be expected.

The effect of reservoir capacity has already been discussed. However, it might be well to point out that increase of reservoir capacity does not decrease the amount of pumping to be done, but simply acts to decrease the time of flooding in case the run-off overtakes the capacity of the plant. The effect is relatively less on short violent periods of precipitation than on longer but equally heavy ones. This will be illustrated in the discussion of rainfall and run-off.

Deep lateral drainage acts to decrease the intensity of run-off. If such laterals are lines of tile, the rate of run-off will still further be decreased, for practically all water must then pass downward through the soil and out through the tile before it can reach the canal, while in the case of open field ditches most of the water can flow over the surface to the ditch and thus directly into the canal. Especially will this effect be noticed as the muck gradually loses its power of rapid absorption.

If the pumping plant be designed to operate continuously its capacity may be much less than that of a plant intended for day use only. As previously mentioned, there is need of the plant at all times of the year. The fact that the water is always promptly pumped out and that all reservoir capacity is quickly available makes a smaller plant capacity practicable.

Nearly all crops grown in this section are cultivated crops, so the rate of run-off will vary but little according to crop. However, the need for rapid removal of all rainfall is greater with truck crops than with general field crops such as cane or corn. With the former very little if any flooding of the surface is allowable, while with the latter the surface may be flooded for perhaps 24 hours several times a year without great damage. The character of crops to be grown should be known and considered in the design of the pumping plant.

The amount and distribution of the rainfall are the most important of all the factors in determining the required capacity of the pumping plant for a given area. While a knowledge of the total yearly and monthly amounts of rainfall, either maximum or average, is important in determining the probable total amount of water to be pumped each year or month, the distribution of the rainfall is the factor that fixes the necessary capacity; that is, the amount of water falling in a period of three or four days must be considered, rather than the amount falling in a year or a month.

On page 5 are tabulated the heaviest storms that have occurred at New Orleans during the past 22 years. It would not be profitable to provide sufficient pumping-plant capacity to care for the run-off of the maximum storm, but only for those that occur so frequently that the resulting damage would be larger than the interest on the additional investment needed to provide for them. By observing the rates of run-off on various typical districts it will be possible finally to determine the ratio that the run-off to be pumped bears to the amount of precipitation in the maximum storm. A determination can then be made of necessary plant capacity, after taking into consideration the factors previously mentioned.

In order to obtain the relation between rainfall and run-off for lands of this section, rain gauges were installed on a number of districts in June, 1909, and a careful log of pumping-plant operation has since been kept. The capacities of the various pumps were obtained by careful ratings. The three areas (Nos. 1, 2, and 8) on which these records were kept have already been described in detail. An examination of the descriptions will show that these districts vary widely in natural characteristics and in the nature of the improvements. In applying the results obtained to any other sections these local conditions should be considered. The daily records for the entire period will not be included here; only the records of heavy storms will be given, these latter being all that are required to determine the proper run-off coefficient. The run-off results vary so widely on the different tracts that they will be discussed separately, and the proper rate of run-off to be provided for will be determined in a preliminary way. It is to be understood, however, that these conclusions are not final and that records of rainfall and run-off extending over longer periods may lead to different ones.

The following table for area No. 2 gives the rainfall and run-off for the eight heaviest storms that occurred during the period, June, 1909, to May, 1912. The stages of water in the reservoirs above or below the general ground surface are given as of 8 a. m. and 8 p. m., these being the usual hours at which the plant was started and stopped when operating in daytime; of course during the heaviest storms considerable pumping was done at night. The condition of the soil at the time of the storm is also noted.

Rainfall, water pumped, and reservoir stages due to heaviest storms occurring on area No. 2, June, 1909, to May, 1912.

[Reservoir capacity, 0.45 inch. Pumping capacity, 1.11 inches.]

Date.	Rain-fall.	Water pumped.	Stage of water in reservoir above (+) or below (-) general surface.		No. of hours land flooded.	Condition of soil before storm.
			8 a. m.	8 p. m.		
	<i>Inches.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>		
1909.						
June 1	0.65	0.00				
2	4.20	.71				
3	.00	1.10	Not recorded.			Well drained, and one-third in cultivation.
4	.39	.40				
5	.00	.22				
Aug. 9	1.14	.00	-0.1	+0.1	18	Do.
10	1.68	.80	+0.2	-1.0		
11	2.80	.90	-2.0	0.0		
12	.02	.80	-0.3	-2.0		
13	.13	.40	0.0	-2.5		
Sept. 19	.65	.00	-0.3	-0.2	54	Do.
20	3.30	.33	-0.1	+0.3		
21	.00	.47	+0.6	+0.3		
22	.00	.72	+0.6	+0.1		
23	.00	.45	-0.4	-0.6		
24	.00	.23	+0.3	-0.2	40	Saturated, and one-third in cultivation.
Dec. 11	2.80	.00	-1.0	0.0		
12	.15	.63	+0.4	+0.2		
13	.00	.62	+0.2	-0.2		
14	.00	.42	+0.3	-1.0		
15	.00	.37	0.0	-2.6		
1910.						
July 1	.50	.15	-1.6	-2.7	36	Well drained, and two-thirds in cultivation.
2	1.82	.23	-2.0	-1.6		
3	3.40	.54	-0.6	-0.9		
4	.36	.77	+0.1	+0.1		
5	.05	1.06	+0.1	0.0		
6	.00	.70	-0.1	-0.7		
7	.00	.41	-1.3	-2.0		

Rainfall, water pumped, and reservoir stages due to heaviest storms, etc.—Con.

Date.	Rain-fall.	Water pumped.	Stage of water in reservoir above (+) or below (—) general surface.		No. of hours land flooded.	Condition of soil before storm.
			8 a. m.	8 p. m.		
			Feet.	Feet.		
1911.	<i>Inches.</i>	<i>Inches.</i>				
Apr. 25	1.02	.00	—2.0	—1.8	0	Well drained, and three-fourths in cultivation.
26	2.02	.56	—1.6	—1.2		
27	.00	.83	—0.5	—2.8		
28	.22	.23	—1.8	—3.5		
Nov. 27	3.00	.47	—0.3	—0.2	0	Do.
28	.00	.88	—0.6	—3.0		
29	.00	.34	—0.3	—2.0		
1912.						
May 1	.30	.00	—3.3	—3.0	0	Well drained, and seven-eighths in cultivation.
2	.00	.00	—2.8	—2.7		
3	.41	.00	—2.6	—2.5		
4	.00	.00	—2.4	—2.3		
5	1.05	.00	—2.1	—1.6		
6	1.21	.55	—1.4	—0.6		
7	.00	.68	—0.5	—0.6		
8	.00	.56	—1.6	—2.6		
9	.00	.11	—2.6	—1.5		

From an examination of the above table it will be seen that it was only during four of these storms that flooding occurred. It is also apparent that if the plant had been operated at full capacity flooding would not have occurred during any of the storms. The flooding was due to unreliable machinery rather than to insufficient theoretical capacity; during the storms of September and December, 1909, the plant was operated at less than half its maximum capacity. In determining the proper capacity of plant to remove these heavy storms it will be necessary to consider only those of August, 1909, and July, 1910. The flooding that occurred on this tract due to these two storms was on only a relatively small portion in the immediate vicinity of the reservoir, and in neither case did it damage crops, as the water was only about 4 inches deep on the ground. In the storm of August, 1909, a pumping capacity of 0.85 inch would have been sufficient to prevent damaging overflow. The total water removed was 2.90 inches. By starting the pumps on August 9, or one day earlier than was done, a capacity of about 0.75 inch would have served to take away all drainage water in time to prevent flooding, as the water would all have been removed more than 24 hours sooner than actually occurred. In the storm of July, 1910, by starting a plant of a capacity of 0.75 inch on July 2 the run-off of the 2d and 3d could have been taken out on the 2d, thus making a gain of 24 hours. It is not possible to estimate exactly the effect of such a gain, but it would appear that the time of flooding would have been reduced to about 12 hours. By applying a pumping capacity of 0.75 inch per day to the other storm periods it will be seen that the run-off could all have been removed without flooding, although the reservoir probably would have stood nearly full for some days. This condition would be allowable two or three times a year without damage to crops. After a period of cultivation of several years the soil on this tract will become more impervious and the intensity of run-off will be greater.

Rainfall, water pumped, and reservoir stages due to heaviest storms occurring on area No. 1, June, 1909, to May, 1912.

[Reservoir capacity 0.34 inch. Pumping capacity 1.45 inches.]

Date.	Rain-fall.	Water pumped.	Stage of water in reservoir above (+) or below (-) general surface.		No. of hours land flooded.	Condition of soil before storm.
			8 a. m.	8 p. m.		
1900.	<i>Inches.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>		
June 1	0.15	0.00	Not recorded.			
2	4.10	.84	-0.7	-0.1	24	Well drained. All cultivated.
3	1.00	1.41	+ .5	+ .3		
4	.00	.76	-3.0	-4.0		
5	.00	.23	-2.0	-4.3		
Sept. 20	4.14	.62	-1.5	-1.4	0	Well drained.
21	.30	1.00	-2.2	-3.0		
22	.00	.50	-2.0	-4.0		
Dec. 11	3.12	.00	-1.0	0.0	40	Saturated.
12	.27	.96	+ .6	+ .6		
13	.00	.90	+ .3	-3.0		
14	.00	.26	-4.0	-1.5		
1911.						
Apr. 8	3.55	.47	-2.0	-1.0	0	Well drained.
9	.00	1.26	-.8	-2.1		
10	.00	.32	-4.0	-2.0		
11	.38	.59	-1.1	-3.0		
12	.00	.20	-2.0	-3.5	48	Do.
Apr. 25	4.05	.65	-2.1	+1.0		
26	2.21	1.16	+1.0	+1.0		
27	.00	1.16	+ .5	0.0		
28	.00	.98	-1.0	-3.5	24	Saturated.
29	.00	.21	-1.5	-3.0		
1912.						
Jan. 6	.22	.00	-1.6	-1.0	24	Saturated.
7	2.18	.00	-.5	0.0		
8	.60	1.16	+ .4	+ .5		
9	.00	1.11	-1.0	-3.5		
Mar. 22	1.70	.00	-2.0	-.4	0	Well drained.
23	2.02	1.02	0.0	-.5		
24	.00	.74	-.8	-1.0		
25	.00	.54	-1.5	-3.5		
Apr. 13	1.42	.55	-1.0	-2.0	48	Do.
14	3.93	.48	-2.0	0.0		
15	.00	1.31	+1.0	+1.0		
16	1.72	1.32	+ .5	0.0		
17	.00	1.05	-1.0	-1.6	36	Do.
18	.00	.37	-2.0	-2.0		
May 1	.26	.00	-1.7	-1.5		
2	.62	.35	-1.2	-3.5		
3	1.20	.60	-1.2	-1.0	36	Do.
4	.00	.50	-2.1	-3.8		
5	2.00	.00	-2.0	-1.5		
6	.00	.64	-1.2	-1.1		
7	.00	.69	-2.5	-3.2	36	Do.
8	.00	.23	-2.0	-3.5		
9	.00	.00	-2.3	-2.2		
10	4.50	.45	-2.0	+ .9		
11	.00	1.42	+1.2	+ .6	36	Do.
12	.00	1.43	0.0	-2.0		
13	.00	.26	-4.2	-3.5		

It will be noted that during six of the nine storms enumerated above flooding occurred. However, only the land immediately along the reservoir canal was flooded and no great damage resulted, i. e., crops were not killed.

In the detailed description of this district a number of conditions were mentioned that were responsible for these large rates of run-off. The small reservoir capacity places the pumping plant at a disadvantage during both heavy and ordinary storms. It allows no reserve in the first case and in the second the plant can not be operated at full capacity for lack of water; only one unit can well be operated continuously until the water is removed. The pumping plant on this tract has not yet failed to remove the water soon enough to prevent any considerable damage to crops. By increasing the storage capacity to

about 0.8 inch the present plant should work to much better advantage. The canal that brings the water from the "front" lands should not be enlarged, as the rapid run-off from these higher lands is at present largely responsible for the flooding. It is doubtful if even a large increase in pumping capacity would be effective if the present reservoir were not improved. With the reservoir enlarged to the usual size of those on other districts, the present pumping plant probably would be of sufficient capacity to give satisfactory drainage.

The drainage from area No. 8 is disposed of by gravity instead of by pumping. The internal canals are large and the outlet canal is of such size that, except in the case of extreme storms, the fluctuation of the water surface in the canals is small; that is, the water is discharged very soon after it reaches the canals. Twelve storm periods are included in the following table:

Rainfall and run-off due to heaviest storms occurring on area No. 8, December, 1909, to April, 1912.

[Gravity drainage system.]

Date.	Rain-fall.	Run-off.	Condition of soil before storm.	Date.	Rain-fall.	Run-off.	Condition of soil before storm.
1909.	<i>Inches.</i>	<i>Inches.</i>		1911.	<i>Inches.</i>	<i>Inches.</i>	
Dec. 11	0.00	0.06	Well drained.	Apr. 24	1.05	.12	Saturated.
12	2.74	.12		25	.00	.11	
13	.00	.34		26	2.72	.59	
14	.80	.33		27	.50	.81	
15	.00	.32		28	.00	.73	
16	.00	.32		29	.45	.44	
17	.33	.31		30	.00	.40	
18	.12	.26		May 1	.99	.55	
19	.00	.21		2	.48	.50	
20	.00	.21		3	.18	.36	
21	.00	.20		4	.18	.28	
1910.				5	.00	.19	
Mar. 9	.00	.05	Dry.	Dec. 18	.00	.07	Well drained.
10	3.11	.10		19	2.66	.08	
11	.00	.18		20	.00	.44	
12	.00	.15		21	.26	.34	
13	.00	.12		22	.85	.28	
May 17	.00	.00	Very dry.	23	.25	.38	
18	.21	.02		24	.00	.35	
19	2.83	.08		25	.32	.27	
20	.00	.06		26	.13	.24	
21	.27	.07		27	.29	.23	
22	1.57	.08		1912.			
23	1.25	.11		Jan. 6	.13	.18	Saturated.
24	.30	.14		7	1.61	.17	
25	.00	.12		8	.80	.49	
July 17	.73	.12		9	.00	.58	
18	.55	.12		10	.00	.38	
19	.65	.34		11	.02	.28	
20	.92	.39		12	.00	.23	
21	.17	.29		Mar. 10	.00	.04	
22	.37	.23		11	2.30	.12	
23	.20	.19		12	.00	.42	
1911.				13	.00	.30	Well drained.
Mar. 21	.00	.02	Dry.	14	.45	.23	
22	3.80	.36		15	.00	.20	
23	.00	.62		Mar. 21	.05	.08	
24	.00	.37		22	3.60	.24	
25	1.15	.38		23	2.40	1.09	
26	.00	.45		24	.00	1.78	
27	.00	.38		25	.00	.84	
28	.00	.24		26	.00	.42	
Apr. 3	.00	.08		27	.00	.32	
4	.10	.11		28	.00	.25	
5	1.10	.16		Apr. 11	.26	.07	Well drained.
6	.00	.12	Well drained.	12	1.39	.07	
7	.00	.08		13	.21	.17	
8	4.03	.69		14	2.10	.71	
9	.00	.98		15	.00	1.42	
10	.00	.48		16	1.60	1.08	
11	1.15	.42		17	.00	.69	
12	.00	.49		18	.00	.44	
13	.00	.33		19	.10	.31	
14	.00	.25		20	.37	.25	
				21	.00	.20	

A wide variation in the rates and amounts of run-off is apparent from the above table, according to the distribution of the rainfall, the time of the year, and especially to the condition of the soil before the storm occurred. The soil is spongelike in its action, and the fact that there are few lateral ditches makes a condition favorable for a large absorption. During the heaviest storms the soil became saturated and the water flowed over the surface to the canals.

In case the run-off from this tract were handled by a pumping plant, the daily run-offs given in the above table would be the amounts available for pumping each day, and if cared for, either by pumping or by storing in a reservoir, flooding would not occur. Therefore by assuming a certain pumping-plant capacity the required capacity of reservoir can easily be determined for these storms and for this particular district. In the following tables different pumping-plant capacities have been assumed and the corresponding necessary reservoir capacities have been calculated. These calculations are based upon the storms of March and April, 1912, these having caused the heaviest run-off. This determination is not made with the idea that the results will be capable of general application, but rather for the purpose of showing a method of finding the proper pumping-plant and reservoir capacities for a given run-off.

Required reservoir capacities for different pumping-plant capacities on area No. 8.

BASED ON STORM OF MAR. 21-25, 1912.

Date.	Rainfall.	Run-off.	Plant capacity 1.4 inches— Water pumped.	Reservoir capacity 0.4 inch— Water in reservoir.	Plant capacity 1.2 inches— Water pumped.	Reservoir capacity 0.6 inch— Water in reservoir.	Plant capacity 1 inch— Water pumped.	Reservoir capacity 0.8 inch— Water in reservoir.	Plant capacity 0.9 inch— Water pumped.	Reservoir capacity 1 inch— Water in reservoir.	Plant capacity 0.8 inch— Water pumped.	Reservoir capacity 1.3 inches— Water in reservoir.
Mar. 21.....	Inches. 0.05	Inches. 0.08	Inches. 0.00	Inches. 0.08	Inches. 0.00	Inches. 0.08	Inches. 0.00	Inches. 0.08	Inches. 0.00	Inches. 0.08	Inches. 0.00	Inches. 0.08
Mar. 22.....	3.60	.24	.32	.00	.32	.00	.32	.00	.32	.00	.32	.00
Mar. 23.....	2.40	1.09	1.09	.00	1.09	.00	1.00	.19	.90	.00	.80	.29
Mar. 24.....	.00	1.78	.38	.00	1.20	.58	1.00	.87	.90	1.07	.80	1.27
Mar. 25.....	.00	.84	1.22	.00	1.20	.22	1.00	.71	.90	1.01	.80	1.31
Mar. 26.....	.00	.42	.42	.00	.64	.00	1.00	.13	.85	.53	.80	.93
Mar. 27.....	.00	.32	.00	.32	.00	.00	1.00	.45	.80	.00	.80	.45
Mar. 28.....	.00	.25	.57	.00	.57	.00	.70	.00	.00	.25	.70	.00

BASED ON STORM OF APR. 11-21, 1912.

Date.	Rainfall.	Run-off.	Plant capacity 1.4 inches— Water pumped.	Reservoir capacity 0.4 inch— Water in reservoir.	Plant capacity 1.2 inches— Water pumped.	Reservoir capacity 0.4 inch— Water in reservoir.	Plant capacity 1 inch— Water pumped.	Reservoir capacity 0.5 inch— Water in reservoir.	Plant capacity 0.9 inch— Water pumped.	Reservoir capacity 0.7 inch— Water in reservoir.	Plant capacity 0.8 inch— Water pumped.	Reservoir capacity 0.9 inch— Water in reservoir.
Apr. 11.....	Inches. 0.26	Inches. 0.07	Inches. 0.00	Inches. 0.07	Inches. 0.00	Inches. 0.07	Inches. 0.00	Inches. 0.07	Inches. 0.00	Inches. 0.07	Inches. 0.00	Inches. 0.07
Apr. 12.....	1.39	.07	.00	.14	.00	.14	.00	.14	.00	.14	.00	.14
Apr. 13.....	.21	.17	.31	.31	.00	.31	.00	.31	.31	.00	.31	.00
Apr. 14.....	2.10	.71	1.02	.00	1.02	.00	1.00	.71	.00	.00	.71	.00
Apr. 15.....	.00	1.42	1.40	.02	1.20	.44	1.00	.52	.90	.70	.80	.62
Apr. 16.....	1.60	1.68	1.10	.00	1.20	.10	1.00	.90	.80	.90	.80	.90
Apr. 17.....	.00	.69	.69	.00	.79	.00	1.00	.21	.90	.49	.80	.79
Apr. 18.....	.00	.44	.44	.00	.00	.44	.65	.03	.00	.03	.80	.43
Apr. 19.....	.10	.31	.00	.31	.75	.00	.00	.31	.00	.74	.34	.00
Apr. 20.....	.37	.25	.56	.00	.56	.25	.56	.00	.00	.59	.25	.00
Apr. 21.....	.00	.20	.45	.20	.45	.00	.00	.20	.79	.00	.00	.45

It will be noted from the foregoing table that the smallest reservoir capacity that is indicated is 0.4 inch in depth of water on the whole area. The size of canal necessary to bring the water to the plant rapidly enough to secure continuous operation and to keep the slope of water surface reasonably small will give a storage capacity of 0.4 inch. In the following summaries the estimated costs of pumping plants and reservoirs are given. The head on pump has been assumed at 6 feet, with 60 per cent efficiency of pump and 90 per cent mechanical efficiency of engine. The figures for cost of plant are for simple slide-valve noncondensing engines and have been taken from the curve in figure 18, which shows the average cost of pumping plants in this State under conditions similar to those on the tract in question. The cost of the reservoir has been calculated at 7 cents per cubic yard and includes only that part of the canal prism between the surface and a depth of 4 feet. It is assumed that the reservoir canal would not be widened below the 4-foot level.

Costs for necessary capacities.

STORM OF MAR. 21-28, 1912.

Capacity of reservoir.	Cost of reservoir.	Capacity of plant.	Cost of plant.	Total cost.
<i>Inches.</i>		<i>Inches.</i>		
0.4	\$4,100	1.4	\$7,000	\$11,100
.6	6,100	1.2	6,100	12,200
.8	8,200	1.0	5,400	13,600
1.0	10,220	.9	4,900	15,120
1.3	13,600	.8	4,700	18,300

STORM OF APR. 11-21, 1912.

0.4	\$4,100	1.4	\$7,000	\$11,100
.4	4,100	1.2	6,100	10,200
.5	5,100	1.0	5,400	10,500
.7	7,150	.9	4,900	12,050
.9	9,200	.8	4,700	13,900

It appears from the above estimate that the cheapest improvements to take care of the storm of March 21-28, 1912, would be a combination of a plant capacity of 1.4 inches and a reservoir capacity of 0.4 inch, and that for the storm of April 11-21, 1912, there should be a plant capacity of 1.2 inches and a reservoir capacity of 0.4 inch. Excepting in the first case, the cost of providing for the second storm is less in each capacity of plant than for the first storm. While the run-offs from these two storms were nearly the same, the time over which the second was distributed was greater, thus allowing smaller capacity of reservoir.

Although as regards first cost alone it appears that the larger plant and small reservoir should be used, there are other factors that enter into the problem. The larger canals would decrease the lift of the plant, as the slope in water surface during operation would not be so great as in the small canals. The operation of the plant, in pumping from a large canal, would not be so intermittent as from a small canal; this would make for better fuel economies. The rate of interest on plant and on reservoir would be the same, but the percentage to be allowed for depreciation and repairs probably would differ somewhat. In removing the run-off from a given storm the smaller plant would have to operate longer, thus increasing the labor charges over those of the larger plant. To determine the proper weight to be given these various factors, continued and detailed records on a number of typical districts are needed, but they are here mentioned to make clear the fact that there are other features

besides the first cost of the improvements to be considered in fixing the proper relative capacities.

LOCATION, DESIGN, AND CONSTRUCTION OF PLANT.

Theoretically the plant should be so located that the water in coming to it will travel the minimum length of reservoir canal. This condition usually would be met if the plant were placed in the center of the district and discharged through a leveed outfall canal to some bordering lake or bayou. In practice, however, the plants ordinarily are located on one side of the tract and on some navigable lake or bayou. This greatly facilitates the transportation of heavy machinery during the erection of the plant, as the ground usually is much too soft to allow the hauling of heavy loads. Fuel also can then be transported cheaply. If the tract has any considerable slope in its surface the logical location of the plant is in the lowest part. However, this part is often very soft, and to secure foundation it may be advisable to locate in some higher and more stable portion. As pointed out in the discussion of levees, there are frequent ridges of silt winding through these swamps, and a plant can often be located on one of these solid ridges. While it would be necessary to use a great many piles under the foundation in either case, the number can be reduced if the plant is located on a ridge.

The foundation under both the machinery and the building of these plants should be of concrete, well supported by piling. A plan of the foundation under the plant at Gueydan has already been shown (fig. 16, p. 51) and is a good illustration of a foundation in this character of soil. The foundation under the plant on area No. 5, already illustrated (fig. 13, p. 45), is also a good one. It will be noted on both these plans that the foundation is surrounded by sheet piling and that under the center of the Des Allemands plant a line of sheet piling has been driven and extended into the concrete. In these soft soils such precautions are necessary. The engine and pump usually are mounted on the same block of concrete, so that any subsequent settlement will not throw them out of line. While buildings to inclose the machinery should be of durable and fireproof construction, they are not called upon to protect the machinery and attendants from low winter temperatures. A frame of structural steel covered with heavy corrugated galvanized iron answers the purpose very well, although in one case a brick building has been erected. These buildings should be capable of resisting the action of the tropical hurricanes, for it is at such times that the need for the plant is greatest.

The selection and arrangement of machinery in centrifugal pumping plants have already been discussed in detail in publications of this office.¹ While the local conditions considered in these publications are somewhat different from those in southern Louisiana, the same principles are involved, and the same general features are to be considered.

As stated previously, the average lift of drainage pumping plants is from 3 to 10 feet. The bulk of the water is lifted little more than 3 feet. Special attention should therefore be given to the reduction of all friction and velocity head losses to a minimum, as a poor arrangement of piping on the pumps may easily double the total head against which they must work. The design of the pump must be especially suited to such low and variable lifts in order to give efficient service, the ordinary centrifugal pump for higher lifts being very inefficient under these local conditions. These pumps should also be so designed that they are able to work under an overload. Increased capacity can then be

¹ U. S. Dept. Agr., Office of Expt. Stas. Bul. 243, Land Drainage by Means of Pumps, by S. M. Woodward; Circ. 101, The Selection and Installation of Machinery for Small Pumping Plants, by W. B. Gregory.

secured by speeding up the pump. The efficiency will be less when working under an overload, but this increased capacity at times of heavy precipitation is very desirable, even if secured at a sacrifice of efficiency. The rated capacity of ordinary centrifugal pumps is based on a velocity of flow, through the discharge opening on the pump, of from 10 to 12 feet per second. Pumps are now being designed to increase this velocity to 14 or 15 feet per second when run at high speeds, i. e., overloads. This will make possible the installation of smaller pumps.

Another point that must be considered in the design of both engine and pump is the gradual increase in static lift that may be expected, due to the subsidence of the muck soils. Of course the amount of this subsidence will depend upon the nature and depth of the original muck, but it will often amount to 2 or even 3 feet in the course of 10 or 15 years. Both the average and the maximum lift will thus be increased by this amount. After a period of perhaps 15 years further subsidence will amount to little.

The total amount of water pumped in a year will affect the character of machinery to be used. The rainfall in this section is greater than in the northern latitudes, and the run-off, consequently, is also greater. The following table gives the yearly rainfall and run-off on three of the districts previously described, and the number of days on which rainfall and pumping occurred for the period from June, 1909, to May, 1912, inclusive.

Yearly and average yearly rainfall, run-off, number of days on which pumps were operated, and number of days on which rain fell on areas Nos. 1, 2, and 8, June, 1909, to December, 1912.

Year.	Area No. 1.				Area No. 2.				Area No. 8.		
	Rain-fall.	Run-off.	Number of days. pumps ran.	Number of days rain fell.	Rain-fall.	Run-off.	Number of days pumps ran.	Number of days rain fell.	Rain-fall.	Run-off.	Number of days rain fell.
1909 ¹	<i>Ins.</i> 42.32	<i>Ins.</i> 16.33	45	66	<i>Ins.</i> 37.21	<i>Ins.</i> 15.83	41	57	<i>Ins.</i> 27.74	<i>Ins.</i> 9.98	62
1910.....	43.08	11.58	45	83	41.48	10.83	55	84	² 42.54	² 15.77	² 68
1911.....	52.32	23.41	69	75	54.56	25.84	102	96	62.22	32.69	108
1912.....	³ 48.22	³ 34.42	³ 81	³ 48	⁴ 50.34	58.86	131	91	65.72	40.59	120
Total.....	185.94	85.74	240	272	192.11	102.84	329	328	198.22	99.03	358
Average, year....	57.21	26.38	74	84	53.36	28.57	91	91	59.53	29.80	108

¹ June to December, inclusive.

² February, September, and October omitted.

³ June to September, inclusive, omitted.

⁴ Large run-off due to excessive seepage through levees.

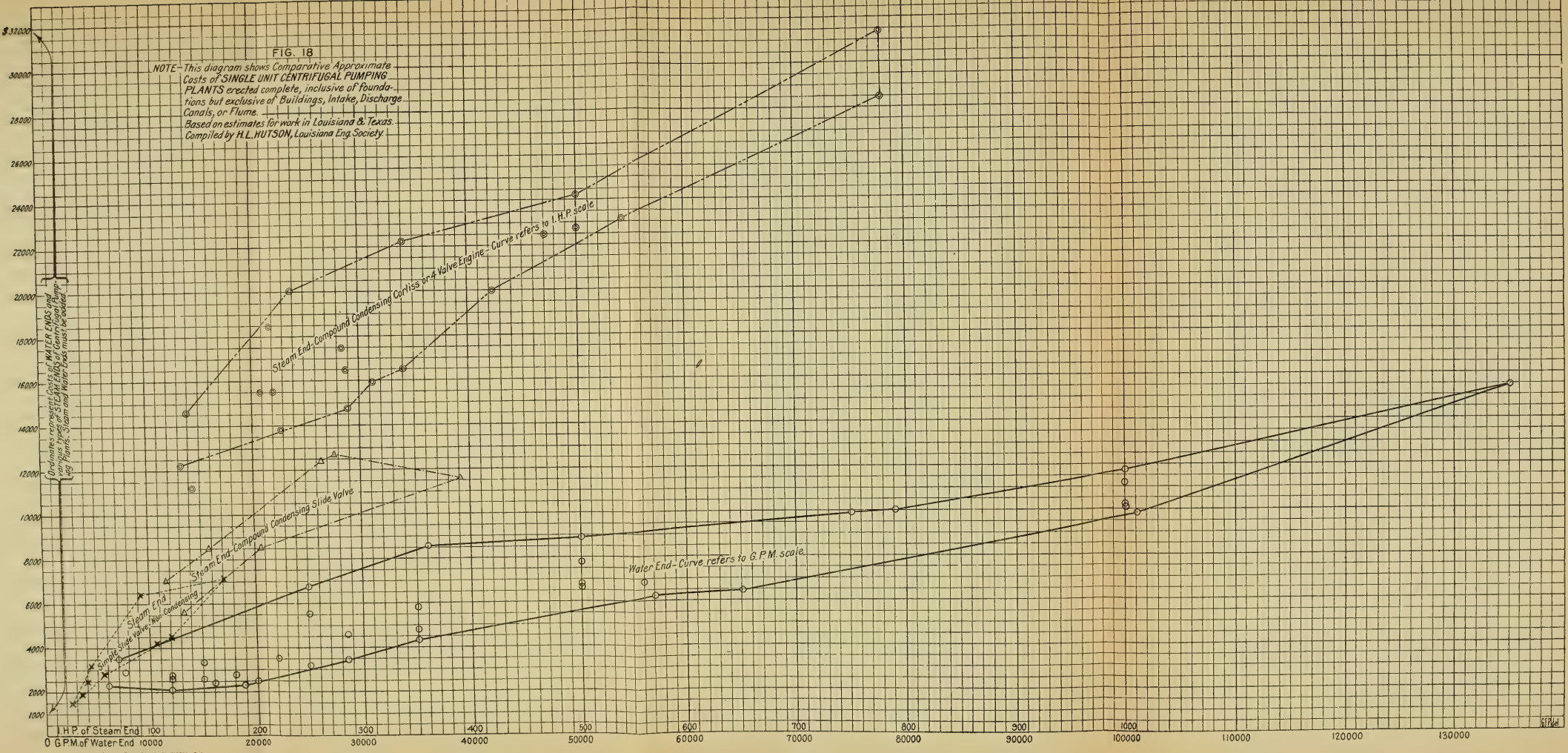
The above table would indicate that an average run-off of about 28 inches per year might be expected and that it would be necessary to operate the pumps on from 70 to 90 days a year. During the 3 years and 7 months that the records were kept the boilers of the plant on area No. 2 were fired up 278 times, and those on area No. 1 189 times in 3 years and 3 months. The average number of times that these boilers were fired per year was 68. This yearly average is higher than should be expected on districts with larger reservoir capacities.

COST OF PUMPING PLANTS.

The cost of drainage pumping plants per indicated horsepower varies widely according to type of machinery, expense of transportation of machinery to site of plant, character of foundation, and difficulty of erection. The last three

FIG. 18

NOTE—This diagram shows Comparative Approximate Costs of SINGLE UNIT CENTRIFUGAL PUMPING PLANTS erected complete, inclusive of foundations but exclusive of Buildings, Intake, Discharge Canals, or Flume.
Based on estimates for work in Louisiana & Texas.
Compiled by H.L. HUTSON, Louisiana Eng. Society.



items will vary greatly according to local conditions. An accompanying diagram (fig. 18) shows comparative approximate costs of single-unit centrifugal pumping plants erected complete, inclusive of foundations, but exclusive of buildings, intake, discharge canals, or flume. These costs are based on estimates for work in Louisiana and Texas, and the diagram is published by courtesy of Mr. H. L. Hutson, of A. M. Lockett & Co. (Ltd.), New Orleans, La. These figures are approximate, but are on the safe side, i. e., they take into consideration construction under unusual difficulties. In making up these costs it was assumed that the effects of the three items which are mentioned as varying according to local conditions would be a constant percentage of the cost of the plant. It is obvious that this diagram should not be used for accurately obtaining the cost of a drainage plant, but that its chief usefulness is in showing the relative cost of the various types of machinery, for deciding upon the most economical size of unit to be used in large plants, and for making approximate estimates of the total cost of plants.

In making the diagram the cost of the plant has been divided into the cost of the "water end," being pump, pump foundation, and piping; and the cost of the "steam end," which includes the engines, boilers, and their foundations and auxiliaries. The cost of the water end is given in terms of gallons per minute of rated capacity, and that of the steam end in terms of indicated horsepower. Owing to the variation in costs, it is necessary to use zones instead of lines to indicate them.

The zone marked "Steam end, compound condensing Corliss or 4-valve engines," includes the cost of this type of engine and water-tube boilers. The zone marked "Compound condensing slide valve" includes the cost of this type of engine and either water-tube or return tubular boilers, according to the size of plant. The zone marked "Simple slide-valve noncondensing" includes the cost of this type of engine and horizontal return tubular boilers. It will be noted that for the higher class engines the cost is not indicated below about 100 horsepower, as engines of this class can not be purchased in smaller sizes than 75 or 100 horsepower.

In estimating the cost of a plant the following steps are necessary. With a given capacity of plant in gallons per minute, estimate the cost of the water end by use of the water-end zone. In order to get the cost of the steam end the indicated horsepower must first be calculated. The water horsepower is first determined, knowing the capacity and lift of the plant; this is then divided by the combined efficiency of the engine, transmission, pump, and piping, which will give the indicated horsepower. By using the various zones of cost of different types of engines, the cost of the steam end can be determined. Then by combining the cost of water end and steam end the total cost of plant will be determined.

COST OF OPERATION.

Full and complete records of pumping operations have not been kept on any district in this section until the present investigation was started in June, 1909. The records of cost of operation are therefore incomplete, and those that have been given are useful in illustrating the need for more efficient machinery rather than as serving as a guide for estimating the cost of operation of drainage plants in this section. On page 78 is a statement showing the comparative fuel costs of several types of pumping plants when removing 12 inches of water from a tract of 1,000 acres at the rate of approximately 1 inch per 24 hours against a total head on pump of 8 feet. This table and the one on page 80 have been prepared by A. M. Lockett & Co. as being applicable to local conditions and are published by their courtesy.

Comparative statement showing relative fuel costs of several types of pumping plants. For 1,000 acres, 6 feet difference in levels, 8 feet total head. Amount pumped = 1 acre-foot per acre per season, at rate of approximately 1¹ acre-inch per acre in 24 hours.

[Prepared by A. M. Lockett & Co., New Orleans, La.]

Water horsepower.	Type of plant.	Efficiencies.			I. H. P. of steam engine.	B. H. P. of gas engine.	Water rate of engine.	Total steam, including 20 per cent for auxiliary and oil burners.	Total fuel oil at 12 pounds evaporation.	Gals. per hr.	Total gasoline at 1 pint per B. H. P. hour.	Total cost of fuel oil per hour at \$1.25 per barrel.	Total cost of gasoline per hour at 12 cents per gallon.	Total fuel cost per year reclaiming and maintaining drainage on basis of removing total 12 inches at pump efficiencies named.										
		Engine.	Belting.	Combined.										100 per cent.	75 per cent.	70 per cent.	65 per cent.	60 per cent.	55 per cent.	50 per cent.	45 per cent.	40 per cent.	35 per cent.	30 per cent.
41	Simple slide-valve engine, belted.....	Pct. 90	Pct. 90	P. ct. 81	H. P. 50.5	Lbs. per I. H. P. hr. 45	Lbs. per hr. 2,726	Lbs. per hr. 227				\$0.88		\$238	\$317	\$340	\$366	\$397	\$433	\$476	\$529	\$595	\$680	\$795
41	Simple slide-valve engine, direct connected.....	90	90	90	45.5	45	2,456	205				.80		218	290	311	336	364	396	436	485	545	623	727
41	Gasoline engine, belted.....	90	90	90	45.5					5.68			\$0.68	184	245	263	283	307	335	368	410	460	526	613
41	Gasoline engine, direct connected.....				41.0					5.11			.61	165	220	236	254	275	300	330	366	412	471	550
41	Simple Corliss engine, belted.....	92	90	82.8	49.5	26	1,544	128				.50		135	180	193	208	225	246	270	300	338	386	450
41	Simple Corliss engine, direct connected.....	92	90	92	44.5	26	1,388	115				.45		122	163	174	188	203	222	244	271	305	350	407
41	Compound condensed slide valve, direct connected.....	90	90	90	45.5	20	1,092	91				.36		98	131	140	151	163	178	196	217	245	280	326
41	Compound condensed Corliss, direct connected.....	92	90	92	44.5	18	961	80				.31		83	111	119	128	138	151	166	184	208	237	276

¹ Specifically, 1.06 acre-inches.

As the headings in the table on page 78 are necessarily much abbreviated a short explanation of those that may seem obscure will be given. The first column gives the water horsepower of the plant of the assumed capacity. The second column states the type of plant, and also whether the engine is belted or direct connected to the pump. Under efficiencies, the third column gives the mechanical efficiency of the engine, the fourth that of the belt, if any, and the fifth the combined efficiency of engine and belt. The sixth column gives the indicated horsepower of the steam engine and the brake horsepower of the gasoline engine. The seventh column shows the pounds of water consumed by the engine, in the form of steam, per indicated horsepower hour; then the total steam used per hour would be the product of the two next preceding columns, plus 20 per cent for use of the usual auxiliaries and oil burners; these figures are shown in column 8. The ninth column gives the amount of fuel oil per hour necessary, assuming that 1 pound of oil will evaporate 12 pounds of water. In like manner column 10 indicates the number of gallons of gasoline required per hour, on the basis of 1 pint of gasoline per brake horsepower hour. The total cost of the fuel per hour (columns 11 and 12) is found by multiplying the total amount used per hour by the unit cost, which is here taken as \$1.25 per barrel of 320 pounds for the fuel oil and 12 cents per gallon for the gasoline. The total cost per year is found by multiplying the cost per hour by 270, this being the number of hours the plant will be required to run to remove a depth of 1 foot of water from the 1,000 acres. Under this heading the first column gives the cost for a pump efficiency of 100 per cent. The figures in the other columns are derived by dividing the first column by the various pump efficiencies.

It will be noted in the above table that efficiencies of pumps are given from 30 to 100 per cent. Of course, the higher limit will never be attained, but the lower one doubtless will be reached when such pumps are worked under a heavy overload. The usual efficiency for average-size plants probably will vary between 55 and 65 per cent. In using this table it must be remembered that the higher-class engines can not be purchased in smaller sizes than 75 horsepower.

In the following table the above summary has been applied to a special case of a tract of 3,500 acres, showing the fuel costs per year for removing depths of water from 2 to 6 feet at the rate of 1 inch in depth per 24 hours. The greater depth of water might be encountered when the tract is first reclaimed, but the usual rate would be about 24 inches in depth per year.

Example of application of comparative statement to special case of 3,500-acre tract, 6 feet difference in levels, estimated total head 8 feet.

[Prepared by A. M. Lockett & Co., New Orleans, La.]

Type of plant.	Total cost of fuel per year at stated run-off.				
	72-inch.	60-inch.	48-inch.	36-inch.	24-inch.
Simple slide-valve engine direct connected to cheap open impeller pump, 40 per cent efficiency.....	\$545×6×3.5=\$11,440	\$545×5×3.5=\$9,540	\$545×4×3.5=\$7,630	\$545×3×3.5=\$5,720	\$545×2×3.5=\$3,815
Same, with 65 per cent efficiency pump.....	\$336×6×3.5= \$7,055	\$336×5×3.5=\$5,880	\$336×4×3.5=\$4,704	\$336×3×3.5=\$3,528	\$336×2×3.5=\$2,352
Compound condensing slide-valve direct connected to 65 per cent efficiency pump.....	\$151×6×3.5= \$3,171	\$151×5×3.5=\$2,642	\$151×4×3.5=\$2,114	\$151×3×3.5=\$1,585	\$151×2×3.5=\$1,057
Saving by using different types of plant.....	{ \$11,440-\$7,055=\$4,385	\$9,540-\$5,880=\$3,660	\$7,630-\$4,704=\$2,926	\$5,720-\$3,528=\$2,192	\$3,815-\$2,352=\$1,463
	{ \$11,440-\$3,171=\$8,269	\$9,540-\$2,642=\$6,898	\$7,630-\$2,114=\$5,516	\$5,720-\$1,585=\$4,135	\$3,815-\$1,057=\$2,758
	{ \$7,055-\$3,171=\$3,884	\$5,880-\$2,642=\$3,238	\$4,704-\$2,114=\$2,590	\$3,528-\$2,192=\$1,336	\$2,352-\$1,057=\$1,295

The last column in this table shows that for removing a 24-inch depth the saving in fuel per year in using a compound condensing slide-valve engine instead of a simple slide-valve engine with the same pump would be \$1,295. The labor charges for operating the two plants would be about equal, and an examination of the diagram of cost (fig. 18, p. 77) will show that the first cost of the plants would be very nearly the same and would be approximately \$13,000. The interest and depreciation charges at 13 per cent would be \$1,690 per year, which, added to the fuel cost of \$1,057, would make for the compound-condensing type a total charge per year of \$2,747, exclusive of labor. This is equivalent to a charge of \$0.78 per acre per year. Labor charges would bring this up to about \$1.06 per acre per year. On districts where the service is very intermittent or that are much smaller than this one, the fuel and labor charges would be relatively larger.

As mentioned above, few pumping districts are keeping careful and complete records of operation of plant. Without such records it is impossible to tell whether or not the plant is being run economically or to ascertain sources of waste. From the standpoint of the owners of the land such records are as essential as are the accounts of any business concern to its proprietors. These records are also essential to the future intelligent design of similar plants. If any progress is to be made in the matter of design and construction, not only of the pumping plant but also of the reservoir system, careful and complete records must be kept. This need of records is more essential for purposes of design and construction than for securing careful operation, because a system that is poorly designed to meet local conditions can never be satisfactory even if operated ever so carefully. The individuals and districts that are interested in drainage by pumping owe it to the future success of this form of reclamation and to their own self-interest to keep such records, for it is possible that much money can be saved in first cost of improvement, as well as in reduced operation charges.

Thus far, in the absence of detailed and reliable data, the design of plant has been based on a number of reasonable assumptions. However, when there is such a variation in these assumptions that the resulting plants for similar districts vary in capacity from 50 to 100 per cent, and in character from the lowest to the highest grade machinery, it is evident that a larger percentage of actual facts is needed as a basis of design in place of so much that is assumed. Owing to a variation in local conditions from one district to another, the records should be extended over a large number of typical districts, and it would be much better if a complete record could be secured from every pumping plant of importance. A few dollars spent in keeping such records will be worth many times the amount to each individual district, and the benefit in general to the work of drainage by pumping will be far-reaching and lasting.

The following form is recommended as one including the essential features of daily operation of plant.

Form for daily pumping records.

Date,

Hour.	Reservoir gauge.	Outfall gauge.	Speed of pump.	Steam pressure	Oil meter.	Rainfall.	Remarks.

It would be well to use one page for each day. The gauges in reservoir and outfall canal should be read before starting and again about one-half hour after starting. If practicable they should be read once an hour during operation and all other items should be so entered. It would also be well to read the oil meter, when oil is burned, before firing the boiler and again after the pumps are started. This will determine the losses due to intermittent operation, a question that is at present a subject of much discussion. If coal or wood is burned, it will not be so convenient to determine the amount consumed, but it should be estimated at least once a month. Other expenses should be carefully recorded and the total expenses of operating a plant should be classified under the following headings: Fuel, labor, supplies, repairs, and superintendence. The records should be kept in such form that the totals for month and year can easily be obtained. The cost per acre per year can then be determined, but to determine the cost of removing a given depth of water over the tract the pumps must be carefully rated. The above form provides for such data that the amount of water pumped can be calculated. If these records are faithfully kept on a large number of districts for a term of years, the resulting data will enable the engineer to design a pumping plant intelligently and with the knowledge that it will give satisfaction, not only in capacity, but in economy.

ACKNOWLEDGMENT.

It is with pleasure that acknowledgment is here made of the helpful spirit of cooperation displayed by railroads, companies installing drainage systems, landowners, and practicing engineers. Almost without exception these have cheerfully cooperated in the investigations and have done much to extend the scope and increase the accuracy of the work.

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Contribution from the Forest Service, Henry S. Graves, Forester.
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SUITABILITY OF LONGLEAF PINE FOR PAPER PULP.

By HENRY E. SURFACE, *Chemical Engineer in Forest Products*, and ROBERT E. COOPER,
Chemist in Forest Products.

SOUTHERN PINES FOR KRAFT PULP.

The southern pines have not, until within the last few years, been considered suitable for paper pulp. Their resinous nature is the chief drawback in most processes of paper making. The recent development in Europe, especially in Sweden and Norway, of the sulphate process, however, and the superior quality of the product made from resinous woods has turned attention to longleaf and other southern pines as a possible source of pulp in this country. These pines have long, thick-walled fibers, and also high specific gravities, implying large yields per cord, and therefore seem particularly adapted for the manufacture, at low cost, of strong wrapping papers. The waste wood from the lumber industry in the South suggests a source of cheap raw material.

While the sulphate process can be used in the manufacture of bleaching pulps, its principal product is an undercooked, nonbleaching, brown pulp known as "kraft" pulp, the term, a German one, signifying strength. True to its name, this pulp produces a remarkably strong paper, very resistant to wear.

Kraft papers, which may be made by the soda as well as by the sulphate process, are especially adapted for wrapping purposes. Wrapping papers stand third among the paper products of the United States, being exceeded in amount and value only by news and book papers. In 1909 the production of wrapping papers of all kinds aggregated 764,000 short tons, with a value of \$42,296,000.¹ The value of wrapping papers imported in 1912 was \$846,500.² Complete

¹ Tariff Board Report, Pulp and News Print Paper Industry, 1911, p. 21. Senate Doc. 31, 62d Cong., 1st sess.

² Bureau of Foreign and Domestic Commerce, Monthly Summary of Commerce and Finance for December, 1912, p. 744.

statistics for recent importations of kraft paper are not available, but in 1908, three years after its introduction into the United States, the imports amounted to between 10,000 and 12,000 tons.¹ In 1912 the imports of unbleached sulphate pulp from Sweden alone were approximately 21,600 short tons, and from Norway 8,400 short tons.²

Manila wrapping papers, including the better imitation manilas, have generally been considered the strongest and best wearing, but the light-weight kraft papers give the same service as manilas almost twice as heavy. Although strong, light-weight wrapping papers are made in this country from sulphite pulps, the imported kraft papers and papers made from imported kraft pulps have proved too formidable competitors for even the best wholly-domestic product of this kind. The immediate success and largely increasing use of kraft products has brought on the market imitations, colored to resemble the genuine, made from strong sulphite pulp or from such pulp together with ground, steamed-wood pulp. Although some of them are quite strong in the light weights, they are not equal to the genuine in other ways. The opportunity for developing an increased domestic output of kraft products from native woods is apparent.

The above-mentioned conditions led the Forest Service to conduct a series of tests at the Forest Products Laboratory, maintained in cooperation with the University of Wisconsin, Madison, Wis., in order (1) to determine the suitability of the southern pines for paper pulps; (2) to ascertain the effects of varying cooking conditions in the sulphate process of pulp making; (3) to compare the sulphate process with the soda process. Only longleaf pine has so far been used in the tests, of which this bulletin gives the results under such preliminary analyses as have been made at this time.

LUMBER WASTE AVAILABLE FOR PULP MAKING.

The total stand of longleaf pine (privately owned) was estimated by the Bureau of Corporations in 1910 at 232 billion feet board measure, while for all southern pines the amount was placed at 384 billion feet. The lumber cut from these pines in 1910 amounted to 14 billion feet. The sawed lumber represents approximately one-half the volume of the log as it comes to the mill. Bark and sawdust, which are valueless for paper making, constitute a large proportion of the waste, but it is safe to say that 20 per cent of the volume of the log, exclusive of the bark, is lost in slabs, edgings, and trimmings. Tops and defective logs left in the woods and small logs which at present are converted into lumber with little or no profit would furnish a supply of raw material for pulp making even greater than that derived from the mill waste.

¹ Pulp and Paper Investigation Hearings, 1909, Vol. V, p. 3041. House Doc. 1502, 60th Cong., 2d sess.

² From estimates made by the Swedish Wood Pulp Association in 1913 and furnished the Forest Service by Mr. M. Gintzler, New York City.

The waste wood mentioned is not as a rule the clean, clear material to which pulp mills have been accustomed. But when the soda and sulphate processes are employed, the presence of knots, pitch pockets and streaks, and remnants of decayed wood and bark are not very objectionable. The expense of handling and preparing slabs and other irregular sizes and shapes, however, is greater than for round pulpwood, so the initial cost of such material must be low enough to offset the extra cost incident to its use.

PULP MAKING PROCESSES APPLICABLE TO LONGLEAF PINE.

Four or five mills are at present using southern pine mill waste for the manufacture of wrapping paper and similar products, three of which employ the sulphate process. Several other sulphate mills are either projected or in course of construction. Because of the resinous nature of the wood the preparation of paper pulp from longleaf pine is confined to the soda and sulphate processes, unless special extraction treatments are employed preliminary to cooking.

The soda process consists in digesting suitably prepared wood with caustic soda (NaOH) solution. The cooking results in dissolving the lignin and resin constituents of the wood, and separating the individual fibers from one another. The action depends partly upon the direct solvent and saponifying power of the caustic soda, and partly upon the hydrolysis of the wood in the presence of water at high temperatures, forming organic acid products which unite with the alkali present. Cellulose, of which the fibers are chiefly composed, withstands the cooking action, except under very severe treatment.

The spent cooking liquor, or "black liquor," is separated from the pulp fibers and evaporated; the residue is calcined in a furnace, and the soda compounds are recovered as "black ash," an impure sodium carbonate (Na_2CO_3). This ash is dissolved in water, and the solution is causticized with freshly burned lime; the resulting caustic soda is again used in cooking. The losses of soda occurring in the operations are made up by adding fresh soda ash (commercial sodium carbonate) previous to causticizing.

The sulphate process is similar to the soda process, except that sodium sulphide (Na_2S) is employed as a cooking chemical in addition to the caustic soda. The sodium sulphide is derived from sodium sulphate (Na_2SO_4), which is added during the recovery operations to make up for the losses, and it is from this chemical that the process derives its name. The sodium sulphate is mixed with the black ash and subjected to a high temperature in a "smelter"; this treatment reduces it to sodium sulphide, although the reaction is not complete. The "smelt," containing sodium carbonate, sodium sulphide, and unreduced sodium sulphate, is dissolved in water and the solution is causticized, as in the soda process, with lime, which has, however,

little action on the sulphide and the sulphate. During cooking the organic acids produced react with the sodium sulphide¹ as well as with the caustic soda, so that in calcining both chemicals are recovered as sodium carbonate. If desired, soda ash may be added to the smelt solution before causticizing in order to increase the proportion of caustic soda in the cooking liquors. Some mills have also found it advantageous to mix with the causticized cooking liquors some of the black liquors diverted from the recovery operations.

The soda and sulphate processes can be applied to extracted or steam-distilled chips from which rosin and turpentine have been removed. Turpentine can also be obtained from resinous chips during the cooking operations by condensing the "relief" from the top of the digester. However, the turpentine is very impure, and in the case of the sulphate process contains organic sulphur compounds from which it is separated with great difficulty.

EXPERIMENTAL METHODS.

KINDS OF TESTS.

The tests made by the Forest Service were of two classes: (1) Autoclave tests and (2) semicommercial tests. The autoclave tests comprised several series of cooks made to determine the effects of varying the cooking conditions of the sulphate process. The semicommercial tests include cooks made by the soda as well as by the sulphate process. The semicommercial sulphate cooks employed such cooking conditions as the autoclave tests indicated would give good results, while the tests using the soda process were made with cooking conditions that would give results comparable to those obtained from the sulphate cooks. Because the semicommercial tests show in a more direct manner the possibilities of preparing paper pulp from longleaf pine, they will be discussed before the autoclave tests.

WOOD USED.

The test material consisted of longleaf pine (*Pinus palustris* Mill.) from two localities, Perry County, Miss. (shipment L-3), and Tangipahoa Parish, La. (shipment L-176). A portion of the former, consisting of edgings containing approximately equal amounts of sapwood and heartwood, was used for cooks 176-1, 2, and 3 of the semicommercial soda tests (Table 3), and another similar portion of the same shipment was used for cooks 1 to 65, inclusive, of the autoclave tests. The average bone-dry weight of the wood used in these autoclave tests was 30.4 pounds per cubic foot green volume; the maximum and minimum values were 36.4 and 26.6 pounds, respectively. The wood was fairly free from resin. The remaining cooks employed

¹ In this reaction volatile organic sulphur compounds having extremely disagreeable odors are produced. Unless these odors are eliminated, or held in check by proper means, sulphate pulp mills are highly objectionable except in sparsely populated regions.

two butt logs (15 and 22 inches diameter) of the Louisiana wood, including all of the sapwood and heartwood. These logs were quite resinous, but were free from knots. They had an average bone-dry weight of 35.5 pounds per cubic foot green volume. The maximum and minimum weights were 40.1 and 32.3 pounds, respectively, for the various determinations.

The material was prepared for cooking by removing the bark and sawing the pieces across the grain into sections five-eighths inch thick, which were then split into chips about three-sixteenths to one-fourth inch by 2 to 6 inches across the grain. The chips were screened to remove sawdust, and each lot was thoroughly mixed so as to be uniform throughout.

APPARATUS.

The semicommercial cooks were made in a vertical, stationary digester¹ consisting of a cast-steel cylindrical shell with top and bottom cones, with a capacity of about 62 gallons. The digester was fitted at the top with a "relief" or vent pipe, a pressure gauge, and a thermometer; and at the side with a gauge glass for noting the height of the liquor. The bottom was arranged for "blowing" the contents after cooking. Heat was furnished partly by passing steam directly into the digester at the bottom and partly by two steam coils placed inside the bottom cone. The pressure and temperature were regulated by admitting either more or less steam into the digester and by relieving any excess pressure by means of the top vent.

The autoclave cooks were made in a horizontal rotary autoclave with a capacity of about 2 gallons. This vessel was made of a 6-inch steel pipe with blank flange ends, fitted with trunnions, to one of which was attached a pressure gauge. A screw-joint handhole opening in the side provided for charging. Heat was furnished by Bunsen-burner flames underneath the autoclave, and the pressures were regulated by increasing or decreasing the heat. The autoclave was not relieved during cooking, and no observations of temperatures were made. The cooked pulps were not blown, as in the case of the semicommercial tests, but the cooking vessel was quickly cooled and the contents poured out.

PROCEDURE IN TESTING.

The liquor charges for the sulphate cooks were prepared by mixing caustic soda and sodium sulphide solutions of known composition, as determined by previous analyses, together with water and dry sodium sulphate. The amounts of each constituent were taken in such proportions that when the whole mixture was charged, with the chips,

¹ The apparatus used in the semicommercial cooks is practically the same as that fully illustrated and described in U. S. Department of Agriculture Bulletin No. 80, "Effects of Varying Certain Cooking Conditions in the Productions of Soda Pulp from Aspen," by Henry E. Surface, 1914.

into the digester or autoclave, the amounts of each chemical per pound of chips (bone-dry basis) was in the desired proportion, and the concentration of chemicals in the digester liquor (including the water in the chips) was of the desired degree. For soda cooks the procedure was similar, except that caustic soda was the only chemical to be taken into consideration. The general procedure in conducting the tests was as follows:

The chips to be used for a cook were sampled and weighed. By means of the sample the amount of moisture in the chips and the equivalent bone-dry weight of the charge were determined. The chips, together with the cooking liquors, were then charged into the autoclave or digester, and the vessel closed. After a cook was completed the crude pulp obtained was washed thoroughly, pressed to remove water, shredded, weighed, and sampled for determining its equivalent bone-dry weight. The pulp was then mixed with water and treated in a Hollander-style beating engine¹ with the roll barely touching the bedplate (light brush) until the soft chips in the pulp had become disintegrated into fibers and the wet fibers had a smooth, slippery feel. The beater roll was then pressed hard down on the bedplate (stiff brush), and the beating operation continued until the pulp was suitable for making wrapping paper, as determined by its "feel." The beaten pulp was then screened through the slots (0.012 inch width) of a diaphragm pulp screen. In all cases the screenings obtained were so small in amount that they were disregarded in the yield calculations. The semicommercial pulps were run over a Pusey and Jones 15-inch Fourdrinier paper machine into rolls of dry paper, while the autoclave pulps were made up into sheets on a small hand mold. The papers thus produced contained the experimental pulps alone, without the addition of any other materials.

DETERMINATION OF YIELDS AND PROPERTIES.

The yield of pulp (bone-dry basis) is usually expressed as a percentage of the bone-dry weight of the chip charge, both weights being determined as explained above. When yields per cord are given they are based on a "solid cord" containing 100 cubic feet of clear wood (green volume) having a bone-dry weight of 35.5 pounds per cubic foot;² or 3,550 pounds per cord.

The strengths of the papers from the semicommercial pulps were determined by means of a Mullen paper tester, five "pop tests" being made on double thicknesses of each paper. The value is expressed as a "strength ratio," which is the average of the five test values in pounds per square inch divided by the average sheet thicknesses

¹ A 25-pound Emerson beater was used for the semicommercial tests and a 1-pound Noble and Wood beater for the autoclave tests. Both makes were equipped with steel fly bars and steel bedplate bars.

² This was the average bone-dry weight of the two butt logs of long leaf pine from Louisiana, the material used in the tests for which yields per cord are given.

in ten-thousandths of an inch, and also as a "strength factor," which is the average of the five pop tests divided by the weight per ream of 500 sheets of paper, each measuring 24 by 36 inches. The relative resistance of the papers to wear was determined by crumpling the sheets in the hand, and all other properties mentioned, except strength, were determined by feel or by observation without the aid of instruments.

DEFINITIONS OF TERMS USED.

While the significance of most of the terms used in recording the test data (Tables 1 to 10, inclusive) is either self-evident or sufficiently clear in view of the previous discussion, there are several which may require explanation.

Water in chips.—The amount of moisture is expressed in percentage of water, based on the calculated bone-dry weight of the chips.

All sodium compounds as Na_2O .—This is the sum of the sodium oxide (Na_2O) equivalents of the amounts of the several constituents entering into the chemical charge. "Total Na_2O " has an analagous significance in the soda process.

Sulphidity.—The sulphidity of the liquor charge is the percentage ratio of the Na_2O equivalent of the amount of sodium sulphide (Na_2S) used to the amount of all sodium compounds present expressed as Na_2O .

Causticity.—This has a similar significance with respect to the amount of caustic soda (NaOH) used.

Initial volume of digester liquors.—The digester liquors include the water in the liquor charge, together with the water in the chips and the water condensed from the steam passed into the digester during cooking. This condensation, of course, does not enter into the calculation of the initial volume.

Apparent condensation.—The apparent condensation is the difference between the calculated initial volume of the digester liquors and the observed volume, as read from a water gauge, at the end of the cook. It roughly represents the amount of steam condensing in the digester during cooking, but does not take into account the volume of the pulp and the differences in temperature of the initial and final liquors, nor the steam and liquid lost during relief.

SEMICOMMERCIAL TESTS.

SULPHATE PROCESS.

The object of the semicommercial sulphate cooks was to secure the best quality of pulp with the highest possible yield. The severity of cooking employed depends largely upon the use for which the pulps are intended. If bleaching or easy bleaching pulps, such as are used in book and other white papers, are desired, more severe cooking

treatments are necessary than if the pulps are to be used in natural-color wrapping papers. The present experiments apply more especially to the latter, for which the important properties are strength, toughness, and resistance to wear. The terms mild, medium, and severe cooking, and undercooked, well-cooked, and overcooked pulps used in the following discussion are significant only with respect to the object of the tests.

MILD COOKING TREATMENTS.

The less severe the cooking of a wood the larger will be the yield of crude pulp. However, there is a point at which the pulp will begin to lose its valuable properties for making wrapping papers. For cook 71 the digesting conditions were outlined to give a much undercooked pulp (see Table 1), but the treatment given the wood was even less severe than is indicated by the recorded data, since a portion of the digester liquor was lost through leakage soon after the cook had been started. The crude unbeaten pulp from this cook was full of soft chips, which, while hard enough to resist the action of a stream of water under pressure, could easily be picked apart with the fingers. The paper made from the beaten pulp had a strength factor of 0.50, was moderately tough, and had fair wearing properties. As a wrapping paper it would be considered of medium grade. The yield, 61.2 per cent, or 2,172 pounds per solid cord, was very high, considering the quality of pulp obtained. Pulps produced under less severe cooking conditions had higher yields (see autoclave tests, pp. 14-24), but the quality was not so good, as evidenced by brittleness, lack of strength, and poor wearing properties.

TABLE 1.—Record of semicommercial tests using the sulphate process.

Cook No.	Weight of chips charged (bone-dry basis.)	Water in chips.	Liquor charge.								Initial volume of digester liquors per pound of chips (bone-dry basis).
			Initial concentrations.						Caus- ticity.	Sul- phid- ity.	
			NaOH.	Na ₂ CO ₃ .	Na ₂ S.	SO ₂ com- pounds as Na ₂ SO ₃ .	Na ₂ SO ₄ .	All sodium com- pounds as Na ₂ O.			
	<i>Pounds.</i>	<i>Per ct.</i>	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Gallons.</i>
171	38.62	34.6	26.5	1.4	13.2	1.8	13.2	38.5	53.3	27.3	0.679
77	38.61	34.7	44.6	2.7	22.3	2.9	22.1	64.9	53.2	27.3	.538
81	23.97	22.7	60.4	3.2	30.0	4.0	30.0	87.6	53.4	27.2	.300
85	23.97	22.7	36.0	1.9	18.0	2.4	18.0	52.3	53.3	27.3	.500
92	23.97	22.6	48.0	2.4	30.0	4.0	30.0	77.5	48.0	30.8	.300
98	23.97	22.6	28.8	1.4	14.4	1.9	14.4	41.8	53.3	27.4	.500
113	25.38	18.2	34.2	1.9	17.1	2.2	18.5	50.4	52.6	27.0	.700
138	25.38	18.2	59.9	3.0	30.0	3.9	30.0	87.0	53.4	27.4	.400
141	25.38	18.2	60.0	3.3	15.0	2.1	30.0	74.4	62.4	16.0	.400
146	25.38	18.2	26.5	1.4	13.2	1.8	13.2	38.5	53.3	27.3	.680
147	26.67	12.5	26.5	1.2	13.2	1.8	13.2	38.4	53.4	27.4	.680
148	26.67	12.5	26.5	1.2	13.2	1.8	13.2	38.4	53.4	27.4	.680

¹ A portion of the digester liquor was lost, due to leaks during the early stages of cooking.

TABLE 1.—Record of semicommercial tests using the sulphate process—Continued.

Cook No.	Chemicals charged per 100 pounds of chips (bone-dry basis).						Duration of cooking.			Maximum cooking temperature.	
	NaOH.	Na ₂ CO ₃ .	Na ₂ S.	SO ₂ compounds as Na ₂ SO ₃ .	Na ₂ SO ₄ .	All sodium compounds as Na ₂ O.	Total.	At zero gauge pressure.	At maximum gauge pressure.		
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Hours.	Hours.	Hours.	° F.	° C.
171	15.0	0.8	7.5	1.0	7.5	21.8	3.0	0.1	2.8	331	166
77	20.0	1.2	10.0	1.3	9.9	29.1	3.0	.2	2.3	331	166
81	15.1	.8	7.5	1.0	7.5	21.9	3.0	.1	2.5	331	166
85	15.0	.8	7.5	1.0	7.5	21.8	3.0	.1	2.5	331	166
92	12.0	.6	7.5	1.0	7.5	19.4	3.0	.25	2.5	331	166
98	12.0	.6	6.0	.8	6.0	17.4	5.0	.1	4.3	331	166
113	20.0	1.1	10.0	1.3	10.8	29.4	3.0	.25	1.0	331	166
138	20.0	1.0	10.0	1.3	10.0	29.0	3.0	.1	2.8	331	166
141	20.0	1.1	5.0	.7	10.0	24.8	3.0	.1	2.5	331	166
146	15.0	.8	7.5	1.0	7.5	21.8	3.0	.2	2.3	338	170
147	15.0	.7	7.5	1.0	7.5	21.8	3.5	.3	2.8	338	170
148	15.0	.7	7.5	1.0	7.5	21.8	3.5	.2	3.0	338	170

Cook No.	Digester pressures per square inch.		Steam pressure per square inch at digester inlet.	Apparatus condensation per pound of chips (bone-dry basis).	Yield of crude pulp (bone-dry basis).		Duration of beater treatment.			Strength ratio of paper.	Strength factor of paper.	Ream weight of papers tested.
	Maximum gauge.	Blowing.					Total.	At light brush.	At stiff brush.			
	Pounds.	Pounds.	Pounds.	Gallons.	Per cord.	Lbs. per solid cord.	Hours.	Hours.	Hours.			Pounds.
171	90	40	105	1 0.20	61.2	2,172	3.5	1.5	2.0	0.60	0.50	76
77	90	40	105	.50	45.3	1,609	3.5	2.0	1.5	1.15	.91	31
81	90	50	103	.58	47.9	1,700	5.0	2.5	2.5	1.08	.93	44
85	90	50	108	-----	52.0	1,846	7.0	3.0	4.0	.91	.87	33
92	90	40	110	.49	48.8	1,733	6.5	2.5	4.0	.86	.70	28
98	90	40	108	.50	51.8	1,839	4.5	1.0	3.5	.60	.56	23
113	90	40	100-95	.32	48.6	1,725	6.0	2.0	4.0	.70	.59	37
138	90	40	110	-----	46.1	1,637	-----	-----	-----	-----	-----	-----
141	90	40	108	-----	44.2	1,569	8.5	4.5	4.0	1.02	.86	36
146	100	40	105	-----	54.9	1,949	9.0	4.0	5.0	.72	.68	45
147	100	40	115	.41	49.1	1,743	6.5	4.0	2.5	.92	.71	37
148	100	40	115	.63	48.4	1,718	8.5	4.0	4.5	1.02	.77	33

(P. L.—138, S. L.—176.)

¹ A portion of the digester liquor was lost, due to leaks during the early stages of cooking.

SEVERE COOKING TREATMENTS.

The effect of more severe cooking treatments, produced mainly by greater initial concentrations and amounts of active cooking chemicals, was evidenced by the thoroughly cooked or overcooked pulps from cooks 77 and 141 (Table 1). The crude pulps were not only free from chips and shives, but also seemed to be soft and fluffy. The papers made from the beaten pulps, however, were of very superior quality with regard to resistance to wear, toughness, and strength, the strength factors being 0.91 and 0.86 for cooks 77 and 141, respectively. Both pulps became slightly hydrated during the beater treatments, which produced a parchmentizing effect and increased the strength and toughness. Either of the papers could be

rubbed or crumpled for a long time without becoming fuzzy, tearing, or showing signs of wear at the place of friction. The papers had also a soft, smooth, greasy, leather-like feel, and were light brown in color, like the imported kraft papers. The yields were rather low for sulphate kraft pulps. For cook 77 the yield was 45.3 per cent, or 1,609 pounds per solid cord, and for cook 141, 44.2 per cent, or 1,569 pounds per solid cord. Under still more severe cooking treatments longleaf pine pulps become very soft and gradually lose their strength and wearing properties. (See autoclave tests, p. 14-24.)

MEDIUM COOKING TREATMENTS.

The above-mentioned cooks show approximately the higher and lower limits of yield in the production of pulps and papers of good quality. However, the better quality of wrapping papers resulted from pulps having the lower yields, and in attempting to secure this better quality, but with higher yields than were obtained for cooks 77 and 141, cooks 85, 98, and 146 were made. For cook 85 the amounts of chemicals and the initial concentrations were decreased from the corresponding conditions for cook 77, while the duration of cooking and the pressure remained practically the same; for cook 98 a further decrease was made in the amounts of chemicals and in the concentrations, but the duration of cooking was increased; for cook 146 the amounts of chemicals and the duration were practically the same as for cook 85, but the concentrations were decreased while the pressure was increased. The cooking conditions, given in full in Table 1, are briefly summarized in Table 2. The resultant papers were in each case of good quality, being tough and resistant to wear, but they were in general not so strong as those from pulps produced under more severe cooking treatments. The strength factors for cooks 85, 98, and 146 were 0.87, 0.56, and 0.68, respectively. There is little doubt, however, that these values could be increased considerably by employing beating and other refining treatments better adapted for these particular pulps than the treatments given them. The yields obtained were quite high, cook 85 yielding 52 per cent, or 1,846 pounds per solid cord; cook 98, 51.8 per cent, or 1,839 pounds per solid cord; and cook 146, 54.9 per cent, or 1,949 pounds per solid cord.

TABLE 2.—Condensed summary of cooking conditions for cooks 77, 85, 98, and 146.

Cook No.	Liquor charge, initial concentrations.		Chemicals per 100 pounds of chips (bone-dry basis).		Duration of cooking.		Maximum gauge pressure per square inch.
	NaOH.	Na ₂ S.	NaOH.	Na ₂ S.	Total.	At maximum gauge pressure.	
	Grams per liter.	Grams per liter.	Pounds.	Pounds.	Hours.	Hours.	Pounds.
77.....	44.6	22.3	20.0	10.0	2.0	2.3	90
85.....	36.0	18.0	15.0	7.5	3.0	2.5	90
98.....	28.8	14.4	12.0	6.0	5.0	4.3	90
146.....	26.5	13.2	15.0	7.5	3.0	2.3	100

All things considered, cooks 147 and 148, which may also be classed with those of medium severity, gave the best results. These two cooks were made under almost duplicate cooking conditions, approximately as follows: Caustic soda and sodium sulphide charged per 100 pounds of chips, 15 and 7.5 pounds, respectively; initial concentration of caustic soda in digester liquor, 26.5 grams per liter; initial volume of digester liquor per pound of chips, 0.68 gallon; total duration of cooking, 3.5 hours, of which 2.8 hours for cook 147 and 3.0 hours for cook 148 were at a maximum gauge pressure of 100 pounds per square inch.

The crude pulps were slightly raw and contained some soft chips, which, however, broke up in the beater. The pulp from cook 148 was hydrated during the beating treatment to such an extent that the paper made from it had a parchment-like appearance, the individual fibers being scarcely distinguishable from each other. This paper had good wearing properties and was very tough, with a strength factor of 0.77. The pulp from cook 147 was not subjected to so long a beating treatment, and the resulting paper was not parchmentized to the same extent as that from cook 148. It had a strength factor of 0.71, however, was very tough, and showed good wearing properties. The yield from cook 148 was 48.4 per cent, or 1,718 pounds per solid cord, and from cook 147, 49.1 per cent, or 1,743 pounds per solid cord.

EFFECTS OF BEATING.

The mechanical treatment given a kraft pulp has as important an influence on the properties of the resulting paper as the cooking treatment itself. A crude pulp which appears to be of little value can be made into strong high-grade paper if the proper beater treatment is employed, while the best pulps can easily be ruined by improper beating. The use of kollergangs or edge runners preliminary to actual beating, or of stone rolls and bedplates in the beaters, and the determination by successive tests of the refining and beating treatments best adapted for a particular pulp undoubtedly would have resulted in papers of much better quality than those obtained. Nevertheless, many of the experimental papers were equal or superior to commercial kraft papers.

The effect of different beater treatments was shown by a single series of tests on some of the crude pulp from cook 71 (Table 1). Separate portions of the pulp were treated in the 1-pound beater for periods of 0.5, 1, 2, 3, and 4 hours with the roll at light brush. The papers resulting from treatments of 2 hours or less were soft and weak, and had poor wearing properties, but for the longer periods the papers were firm and tough, with good wearing properties. Under the 4-hour treatment the fibers became hydrated, and a parchment-like paper resulted. The fibers of longleaf pine when reduced by the sulphate process seem to take up water and to become hydrated very

quickly. For all of the semicommercial tests previously mentioned (Table 1) this effect, indicated by the smooth, greasy feel of the wet paper stock, was obtained with from 2 to 4 hours' beater treatment.

WOOD REQUIRED FOR 1 TON OF PULP.

It has been shown that sulphate kraft pulps of fairly good strength and toughness can be obtained from longleaf pine with yields (bone-dry basis) as high as 61 per cent, or 2,170 pounds per solid cord¹ in case of wood as heavy as that tested. For the production of the best grades of wrapping papers, which equal or excel in quality the imported sulphate kraft papers, the yield of pulp would be approximately 51 per cent, or 1,800 pounds (bone-dry) per solid cord. This is equal to a ton (2,000 pounds) of nominally air-dry pulp.² However, it should be remembered that for wood either lighter or heavier than that on which this calculation is based the amount required per ton of pulp would be correspondingly greater or less, unless the differences in weight were due to resin alone.³

COMPARISON OF THE SODA AND SULPHATE PROCESSES.

Table 3 contains the record of the semicommercial soda tests. The best results in both yield and quality were obtained in the case of cook 152. This cook employed 20 pounds of caustic soda per 100 pounds of wood at an initial concentration of 79.7 grams per liter and 5 hours' cooking at 110 pounds gauge pressure, the total duration being 6 hours. The resulting paper was very strong (strength factor 0.90) and the feel and wearing properties were also exceptionally good for a soda pulp. The yield was 48 per cent, or 1,704 pounds per solid cord.

TABLE 3.—*Record of semicommercial tests using the soda process.*

Cook No.	Weight of chips charged (bone-dry basis).	Water in chips.	Liquor charge.				Initial volume of digester liquor per pound of chips (bone-dry basis).	Chemicals charged per 100 pounds of chips (bone-dry basis).		
			Initial concentrations.			Causticity.		NaOH.	Na ₂ CO ₃ .	Total. Na ₂ O.
			NaOH.	Na ₂ CO ₃ .	Total. Na ₂ O.					
	Pounds.	Per cent.	Grams per liter.	Grams per liter.	Grams per liter.	Per cent.	Gallons.	Pounds.	Pounds.	Pounds.
102....	23.97	22.6	84.0	3.4	67.1	97.0	0.538	37.7	1.5	30.1
136 ¹	25.37	18.3	59.9	2.3	47.8	97.2	.400	20.0	7.7	16.0
144.....	25.38	18.2	90.0	3.4	71.7	97.2	.400	30.0	1.1	23.9
149.....	25.89	12.0	90.2	3.2	71.8	97.4	.332	25.0	.9	19.9
150.....	25.89	12.0	90.2	3.2	71.8	97.4	.332	25.0	.9	19.9
151.....	25.89	12.0	90.2	3.2	71.8	97.4	.332	25.0	.9	19.9
152.....	25.89	12.0	79.7	1.8	62.9	98.3	.301	20.0	.5	15.8
176-1 ² ..	41.89	14.6	90.0	2.7	71.3	97.8	.333	25.0	.8	19.8
176-2 ² ..	41.89	14.6	90.0	2.42	71.2	98.0	.266	20.0	.5	15.8
176-3 ² ..	41.89	14.6	90.0	2.42	71.1	98.0	.267	20.0	.5	15.8

¹ Weighing 3,550 pounds; see p. 6.

² Standard moisture content of 10 per cent or 100 pounds air-dry weight equals 90 pounds bone-dry weight.

³ The average specific gravity (oven-dry weight, green volume) of all of the longleaf pine from Louisiana in the shipment from which the two test logs were taken, including bolts cut higher up in the trunks of the same trees and material from several additional trees, was 0.528. (See Forest Service Circular 213, Mechanical Properties of Woods Grown in the United States, 1913, Table 1.) This is equal to a weight per cubic foot of 33 pounds in comparison with the 35.5 pounds obtained for the two butt logs.

TABLE 3.—Record of semicommercial tests using the soda process—Continued.

Cook No.	Duration of cooking.			Maximum cooking temperature.		Digester pressures per square inch.		Steam pressure per square inch at digester inlet.	Apparent condensation per pound of chips (bone-dry basis).
	Total.	At zero gauge pressure.	At maximum gauge pressure.			Maximum gauge.	Blowing.		
	Hours.	Hours.	Hours.	° F.	° C.	Pounds.	Pounds.	Pounds.	Gallons.
102.....	3.0	0.2	2.5	331	166	90	40	115	0.55
136 ¹	6.0	.2	5.3	331	166	90	45	115	.55
144.....	6.0	.2	5.5	338	170	100	40	110	.80
149.....	6.0	.2	5.0	338	170	100	40	122	-----
150.....	9.3	.3	8.3	307	153	60	40	120	-----
151.....	4.5	.2	3.8	361	183	140	40	142	1.02
152.....	6.0	.2	5.0	345	174	110	40	125	.55
176-1 ²	7.0	.5	6.0	338	170	100	-----	110	.94
176-2 ²	7.0	.3	6.0	338	170	100	-----	115	.76
176-3 ²	8.0	.3	7.0	338	170	100	-----	110	.91

Cook No.	Causticity of black liquor at end of cook.	Efficiency in use of NaOH.	Yield of crude pulp (bone-dry basis).		Duration of beater treatment.			Strength ratio of paper.	Strength factor of paper.	Ream weight of papers tested.
					Total.	At light brush.	At stiff brush.			
	Per cent.	Per cent.	Per cent.	Lbs. per solid cord.	Hours.	Hours.	Hours.			Pounds.
102.....	-----	-----	47.2	1,676	4.0	2	2.0	0.43	0.41	42
136 ¹	-----	-----	50.9	1,808	6.5	2	4.5	.55	.54	60
144.....	-----	-----	39.8	1,413	6.0	6	0.0	1.04	.84	48
149.....	22.7	76.7	44.1	1,566	6.5	2	4.5	1.04	.84	37
150.....	41.6	57.3	52.0	1,846	9.0	5	4.0	.53	.56	43
151.....	17.6	81.9	37.6	1,335	6.0	6	0.0	.91	.80	46
152.....	11.2	88.6	48.0	1,704	8.5	4	4.5	1.05	.90	37
176-1 ²	-----	-----	48.6	-----	-----	-----	-----	-----	-----	-----
176-2 ²	-----	-----	51.1	-----	-----	-----	-----	-----	-----	-----
176-3 ²	-----	-----	50.4	-----	-----	-----	-----	-----	-----	-----

(P. L.—138, S. L.—176; P. L.—164-1.)

¹ Five pounds of sodium chloride (table salt) per 100 pounds of chips were used in addition to the chemicals indicated. However, it will be shown later that sodium chloride has little or no effect. (See p. 19.)

² Shipment L-3a from Mississippi was used as the test material. Data for these three cooks have been published previously in Forest Service unnumbered bulletin, "Paper Pulp from Various Forest Woods," by Henry E. Surface, 1912. Specimens of natural color and bleached pulps accompanied the data.

Cook 150 afforded a yield of 52 per cent, or 1,846 pounds per solid cord, but the quality was not so good as in the case of cook 152, the paper being quite weak (strength factor 0.56) with a correspondingly low resistance to wear. The papers resulting from cooks 144, 149, and 151 were all of very good quality, having high strength ratios and good wearing properties, but the yields were considerably lower than for cook 152.

Soda pulps from longleaf pine tend to be soft and fluffy, even when slightly undercooked, or chippy. Proper beater treatments will remedy this to some extent, but the pulp does not become so well hydrated nor attain the same smooth, greasy feel during beating as the sulphate pulps, and the resultant papers do not show the parchmentized effect so characteristic of the sulphate papers. On the paper machine soda stock runs "free," while sulphate stock runs "slow," provided, of course, both kinds of stock are handled similarly in the beater.

The soda papers were inferior to the sulphate papers in resistance to wear; the latter could be rubbed and crumpled for a long time without showing signs of wear, while the former had a tendency to become fuzzy and tear under similar treatment. Even those sulphate pulps at very high yields had wearing qualities equal to the best soda pulps. There is little doubt that higher yields of good kraft pulp can be obtained with the sulphate process than with the soda process. Sulphate pulps of fairly good quality can be obtained with yields as high as 61 per cent, while the limit for soda pulps is approximately 50 per cent. With higher yields the soda pulps lose strength and toughness and become brittle. A sulphate pulp with a 60 per cent yield can be made into a medium grade of kraft wrapping paper, while a soda pulp having the same yield will produce only a very inferior grade. Considering bursting strength alone, equally strong papers can be made by either process.

The main advantage of the sulphate process over the soda process is that in the former the pulp can be very much undercooked and still produce a fair quality of paper, while a soda pulp must be comparatively well cooked before a good paper can be made from it. Moreover, the best sulphate kraft pulps were obtained with a total duration of cooking of only 3.5 hours, while in the soda tests 6 hours were required to secure the best results.

AUTOCLAVE TESTS.

The autoclave tests, which, as previously explained, preceded the semicommercial tests, were made to determine the effects of varying the cooking conditions in the production of sulphate pulp. The cooking conditions investigated were:

- (1) Amounts of the various cooking chemical employed.
- (2) Cooking pressures or temperatures.
- (3) Durations of cooking.
- (4) Initial concentrations of chemicals in the digester liquors.

Aside from the chemicals normally present in sulphate cooking liquors—that is, caustic soda, sodium sulphide, sodium sulphate, and sodium carbonate, the effects of sodium chloride and sulphur in conjunction with caustic soda were studied. The tests, Tables 4 to 10, inclusive, were made in series, in any of which all cooking conditions except the one under observation were held as nearly constant as possible.

The amounts of sodium carbonate and of SO_2 compounds expressed as Na_2SO_3 in the cooking liquors were in general small and no mention of them is made in the tabulated data. The amounts of sodium sulphate present are indicated only relatively, except in Tables 6 and 10.

EFFECTS OF VARYING AMOUNTS OF CAUSTIC SODA.

The effect of varying amounts of caustic soda on the yield of crude pulp is shown in Table 4. Two series of tests were made, differing in the amounts of sodium sulphate and sodium sulphide employed. In the first series increasing the amounts of caustic soda from 15 to 90 pounds per 100 pounds of wood resulted in a decrease in the yield of from 52 to 27.7 per cent. This decrease, however, was not directly proportional to the increase of caustic soda used, as values of this chemical between 30 and 50 pounds had little effect in varying the yield. For higher and lower values the effect was quite pronounced. In the second series a larger amount of sodium sulphide was used, and consequently the yields were lower for corresponding amounts of caustic soda, but variations in the amounts of this chemical produced similar effects.

TABLE 4.—*Effect of varying amounts of caustic soda (NaOH) on the yield of pulp.*

Weight of chips charged (bone-dry basis).....	pounds..	0.986	to	1.007
Water in chips.....	per cent..	10.2	to	12.6
Initial volume of digester liquors per pound of chips (bone-dry basis).....	gallons..	0.650	to	0.690
Duration of cooking, total.....	hours.....			3.0
Duration of cooking at zero gauge pressure.....	do.....			0.1
Duration of cooking at maximum gauge pressure.....	do.....			2.3
Maximum gauge pressure per square inch.....	pounds.....			90
Total duration of beater treatment (at light brush only).....	hours.....			0 or 1

FIRST SERIES.

Cook No.	Liquor charge.					Chemicals charged per 100 pounds of chips (bone-dry basis).			Yield of crude pulp (bone-dry basis).
	Initial concentrations.			Causticity.	Sulphidity.	NaOH.	Na ₂ S. ¹	All sodium compounds, as Na ₂ O.	
	NaOH.	Na ₂ S. ¹	All sodium compounds, as Na ₂ O.						
	Grams per liter.	Grams per liter.	Grams per liter.	Per cent.	Per cent.	Pounds.	Pounds.	Pounds.	Per cent.
31	26.3	13.1	38.1	53.6	27.5	15.0	7.5	21.7	52.0
55	52.1	13.0	57.9	69.7	17.9	30.0	7.5	33.4	42.9
56	69.6	13.0	72.0	74.9	14.4	40.0	7.5	41.4	39.6
57	87.0	13.0	85.6	78.7	12.1	50.0	7.5	49.2	42.1
58	104.4	13.0	99.7	81.1	10.4	60.0	7.5	57.3	40.0
59	121.8	13.0	113.6	83.1	9.1	70.0	7.5	65.3	33.3
60	156.6	13.0	139.3	87.1	7.4	90.0	7.5	80.1	27.7

SECOND SERIES.

29	35.4	44.4	84.2	32.6	42.0	19.9	25.0	47.4	42.3
28	55.3	45.9	101.9	42.1	35.8	30.0	24.9	55.2	38.2
33	52.7	43.9	99.5	41.0	35.1	30.0	25.0	56.6	37.0
54	60.8	43.3	104.5	45.1	32.9	35.0	24.9	60.1	39.9
32	70.1	43.9	113.0	48.5	30.9	39.9	25.0	64.4	34.8
27	73.8	45.9	116.7	49.0	31.3	40.0	24.9	63.3	35.0
53	76.6	43.3	117.0	50.8	29.4	44.1	24.9	67.3	38.6
43	88.2	44.3	128.3	53.2	27.4	49.8	25.0	72.5	36.8
26	88.3	44.4	126.8	54.3	27.9	50.0	25.0	71.4	37.6
49	104.2	43.4	139.2	58.0	24.8	60.0	25.0	80.2	31.8
52	121.6	43.2	152.4	61.9	22.6	70.0	24.9	87.8	31.8
51	139.0	43.5	166.6	64.6	20.7	80.0	25.0	95.8	28.1

(P. L.—138, S. L.—3b.)

¹ With a few minor exceptions, the same values apply to the Na₂SO₄.

The best quality of pulp was obtained with cook 31, using 15 pounds of caustic soda per 100 pounds of wood. This resulted in a slightly undercooked product, which came from the autoclave in the

form of soft chips. The chips did not break up during the washing operation, but were readily pulped by beater treatment. The pulp was strong, tough, and resistant to wear. When larger amounts of caustic soda were employed the pulp tended to be soft, fuzzy, and less strong, while for smaller amounts it was harsh and brittle. (See cooks 39 and 40, Table 6.) In the second series of tests (Table 4) the conditions were such that all of the pulps were overcooked if considered for kraft papers.

The higher the amount of caustic soda employed, the lighter in color was the pulp. The extremes for the first series of tests were brown in the case of cook 31 and light gray in the case of cook 60. For the second series of tests the color change was less noticeable.

EFFECTS OF VARYING AMOUNTS OF SODIUM SULPHIDE.

The effects of varying the amount of sodium sulphide were shown by three series of tests employing different amounts of caustic soda and of sodium sulphate. The cooking conditions and resultant yields are given in Table 5.

TABLE 5.—*Effect of varying amounts of sodium sulphide (Na_2S) on the yield of pulp.*

Weight of chips charged (bone-dry basis).....	pounds.....	0.996 to 1.043
Water in chips.....	per cent.....	11.0 to 16.0
Initial volume of digester liquors per pound of chips (bone-dry basis).....	gallons.....	0.662 to 0.683
Duration of cooking, total.....	hours.....	3.0
Duration of cooking at zero gauge pressure.....	do.....	0.1
Duration of cooking at maximum gauge pressure.....	do.....	2.0 to 2.5
Maximum gauge pressure per square inch.....	pounds.....	90
Total duration of beater treatment (at light brush only).....	hours.....	0, 1, or 2

FIRST SERIES.¹

Cook No.	Liquor charge.					Chemicals charged per 100 pounds of chips (bone-dry basis).			Yield of crude pulp (bone-dry basis).
	Initial concentrations.			Caus- ticity.	Sulphid- ity.	NaOH.	Na ₂ S. ²	All sodium com- pounds, as Na ₂ O.	
	NaOH.	Na ₂ S. ²	All sodium com- pounds, as Na ₂ O.						
	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
31	26.3	13.1	38.1	53.6	27.5	15.0	7.5	21.7	52.0
34	26.3	26.3	49.6	41.1	42.2	15.0	15.0	28.3	47.4
35	26.3	43.9	62.4	32.7	56.0	15.0	25.0	35.5	44.5
36	26.3	70.2	88.0	23.2	63.5	15.0	40.0	50.0	39.9
37	26.5	88.3	103.8	19.7	67.5	15.0	50.0	58.9	40.3

SECOND SERIES.¹

133	27.2	1.8	31.1	67.7	4.6	15.0	1.0	17.2	68.9
134	27.2	5.4	34.4	61.3	12.6	15.0	3.0	19.0	67.6
139	27.0	9.0	37.3	56.1	19.2	15.0	5.0	20.7	60.1

THIRD SERIES.¹

129	35.3	3.7	39.4	69.4	7.4	20.0	2.1	22.3	64.3
130	35.9	7.2	43.0	64.8	13.3	20.0	4.0	23.9	53.7
131	36.0	10.8	46.3	60.2	18.5	20.0	6.0	25.7	49.7
132	36.0	14.4	49.6	56.2	23.1	20.0	8.0	27.6	47.7

(P. L.—138.)

¹ The Mississippi wood (shipment L-3b) was used for the first series and the Louisiana wood (shipment L-17c) for the second and third series.

² With a few minor exceptions, the Na_2SO_4 amounted to one-half of these values for the first and third series and to two-thirds of these values for the second series.

In the first series of tests, with an increase in the amount of sodium sulphide from 7.5 to 50 pounds per 100 pounds of wood, the yield decreased from 52 to 40.3 per cent. For amounts of 25 pounds or less the pulps were of good quality, being strong with good wearing properties, but for larger amounts the pulps became soft and fuzzy and evidently were overcooked.

In the second series, increasing the amount of sodium sulphide from 1 to 5 pounds per 100 pounds of wood resulted in a decrease in the yields from 68.9 to 60.1 per cent. The largest amount (5 pounds) afforded the best pulp, considering strength and wearing properties; the other pulps were much undercooked and quite brittle.

The third series of tests, using a larger amount of caustic soda (20 pounds), showed the effect of increasing the amount of sodium sulphide from 2.1 to 8 pounds per 100 pounds of wood. Under these conditions, the yield was decreased from 64.3 to 47.7 per cent. The pulp obtained when using 2.1 pounds of sodium sulphide was slightly undercooked and somewhat brittle. The other pulps had fair strength and wearing properties and could be used for making a medium grade of wrapping paper.

As the amount of sodium sulphide was increased, the disagreeable odor arising from the cooking was more noticeable, being much more offensive for cook 37 (50 pounds Na_2S per 100 pounds of wood) than for cook 31 (7.5 pounds Na_2S). Increasing the amount of sodium sulphide resulted in lighter-colored pulps, that from cook 37 being considerably lighter in color than from cook 31.

Sodium sulphide is not so severe in its action on wood as caustic soda. A cook of 8 hours' duration was made with sodium sulphide only, using 40 pounds per 100 pounds of wood and a maximum cooking pressure of 100 pounds per square inch. A yield of 41 per cent was obtained, while a similar cook using caustic soda alone in the proportion of 20 pounds per 100 pounds of wood had a yield of 44.3 per cent. This indicates that caustic soda is almost twice as effective as sodium sulphide in reducing the wood to pulp. The color of the pulp produced when using caustic soda alone was lighter than when using sodium sulphide alone.

EFFECTS OF SODIUM CARBONATE.

Sodium carbonate occurs in the commercial sulphate liquors due to incomplete causticization. That it is of no assistance in reducing longleaf pine was shown by a cook made with 40 pounds of this chemical, 10 pounds of caustic soda, and 5 pounds of sodium sulphide per 100 pounds of wood. The duration of cooking was 7 hours and

the maximum gauge pressure was 100 pounds per square inch. The product came from the autoclave in the form of hard, black chips which were quite "raw" on the inside; the yield was not determined. In comparison with this result, cook 40 (Table 6), using, per 100 pounds of wood, 10 pounds of caustic soda, 5 pounds of sodium sulphide, and 5 pounds of sodium sulphate (the latter being of no assistance in cooking), also afforded a product in the chip form. These chips, however, were soft, and could easily be picked apart with the fingers. Of the 3 hours' total duration for this cook, 2.3 hours were at a maximum pressure of 90 pounds. The yield was 65.7 per cent. While it is hardly safe to base a general conclusion upon a single trial, this test indicates that sodium carbonate, at least when present in considerable quantity, retards or diminishes the effects of the caustic soda and sodium sulphide.

EFFECTS OF SODIUM SULPHATE.

Sodium sulphate is present in the commercial cooking liquors, due to incomplete reduction of the sulphate to sulphide during the smelting operations. Like sodium carbonate, it is of practically no assistance in cooking. A cook of 3 hours' duration and 90 pounds maximum gauge pressure was made, using sodium sulphate in the proportion of 50 pounds per 100 pounds of wood, which yielded 86.3 per cent, while another cook of the same duration and pressure but without any chemicals whatever (that is, using pure water alone) had a yield of 89.1 per cent. Allowing for experimental errors, there was little difference between the results of these two cooks, and in neither case could the product be beaten into pulp.

A cook was also made, using 40 pounds of sodium sulphate, 10 pounds of caustic soda, 5 pounds of sodium carbonate, and 5 pounds of sodium sulphide per 100 pounds of wood; the duration was eight hours and the maximum gauge pressure was 100 pounds per square inch. Only hard black chips were obtained, of no value whatever for pulp. As in the case of the sodium carbonate, there is an indication that sodium sulphate retards the action of the other chemicals. To prove this further tests are necessary.

EFFECTS OF VARYING ALL CHEMICALS IN SAME PROPORTION.

A series of tests was made varying the amounts of all sodium compounds present in sulphate cooking liquors. The several constituents were kept constant in regard to each other in the proportion of 50 parts caustic soda, 25 parts sodium sulphide, and 25 parts sodium sulphate. For convenience the amounts of the different chemicals have been computed to a common basis, and the combined values are expressed as Na_2O (sodium oxide).

The yields shown in Table 6 varied from 65.7 per cent for 14.5 pounds of total Na_2O per 100 pounds of wood to 36.8 per cent for 72.5 pounds of total Na_2O . The conditions indicated for cook 31 afforded the best results with regard to both yield and quality of pulp produced. With the higher yields the pulps were harsh and had less resistance to wear. Nevertheless, wrapping papers of medium grades could be made from these pulps. The pulp from cook 30 was of good quality, with strength and wearing properties equal to that from cook 31, but the yield was not so high. Cooks 43, 26, and 38 were duplicates of each other, and show the accuracy attained in the yield determinations. The pulps from these three cooks were soft and fluffy, and had poor strength and wearing properties, due to overcooking.

TABLE 6.—*Effect of varying amounts of all sodium compounds on the yield of pulp.*

Weight of chips charged (bone-dry basis).....	pounds..	0.996 to 1.007
Water in chips.....	per cent..	10.2 to 11.5
Causticity of liquor charge.....	do.....	53.2 to 54.3
Sulphidity of liquor charge.....	do.....	27.4 to 27.9
Initial volume of digester liquors per pound of chips (bone-dry basis).....	gallons..	0.675 to 0.683
Duration of cooking, total.....	hours..	3.0
Duration of cooking, at zero gauge pressure.....	do.....	0.1
Duration of cooking, at maximum gauge pressure.....	do.....	2.0 to 2.3
Maximum gauge pressure per square inch.....	pounds..	90
Total duration of beater treatment (at light brush only).....	hours..	0, 1, or 2

Cook No.	Liquor charge, initial concentrations.				Chemicals charged per 100 pounds of chips (bone-dry basis).				Yield of crude pulp (bone-dry basis).
	NaOH.	Na_2S .	Na_2SO_4 .	All sodium compounds as Na_2O .	NaOH.	Na_2S .	Na_2SO_4 .	All sodium pounds as Na_2O .	
	Grams. per liter.	Grams. per liter.	Grams. per liter.	Grams. per liter.	Pounds.	Pounds.	Pounds.	Pounds.	Per cent.
40	17.6	8.8	8.8	25.5	10.0	5.0	5.0	14.5	65.7
39	21.2	10.6	10.6	30.7	12.0	6.0	6.0	17.4	60.2
31	26.3	13.1	13.1	38.1	15.0	7.5	7.5	21.7	52.0
30	35.6	17.8	17.8	51.3	20.0	10.0	10.0	28.9	47.0
43	88.2	45.3	45.3	128.3	49.8	25.0	25.6	72.5	36.8
26	88.8	44.4	44.4	126.8	50.0	25.0	25.0	¹ 71.4	37.6
38	88.2	44.1	44.1	127.6	50.0	25.0	25.0	¹ 72.4	36.6

(P. L.—138, S. L.—35.)

¹ The Na_2O values for cooks 26 and 38 differ mainly because of different amounts of Na_2CO_3 which are not separately recorded in the table.

EFFECTS OF SODIUM CHLORIDE.

A few tests were made to determine whether or not the use of sodium chloride in conjunction with caustic soda would result in firmer and less fuzzy pulps, more resistant to wear, than are ordinarily produced with the soda process. If this were possible a process might be developed to produce pulps similar to those obtained with the sulphate process without the disagreeable odors so characteristic of it. Table 7 shows a comparison between cooks made with caustic soda alone and with caustic soda and sodium chloride. It is not probable that sodium

chloride has an effect on the yield, as is evidenced by the data for cooks 128 and 137. Both cooks employed 20 pounds of caustic soda per 100 pounds of wood, but the former used 5 pounds of sodium chloride in addition. The yields from the two cooks were identical. The use of sodium chloride appeared to improve the qualities of the pulps somewhat, but they were much inferior to sulphate pulps at similar yields. The few advantages attending the use of sodium chloride preclude the possibility of this modification of the soda process being of commercial value.

TABLE 7.—*Effect of sodium chloride (NaCl) used in conjunction with caustic soda (NaOH) on the yield of pulp.*

Weight of chips charged (bone-dry basis).....	pounds..	0.910 to 1.043
Water in chips.....	per cent..	15.1 to 22.0
Causticity of liquor charge (disregarding NaCl).....	do....	96.0 to 97.2
Duration of cooking at zero gauge pressure.....	hours..	0.1
Maximum gauge pressure per square inch.....	pounds..	90
Total duration of beater treatment (at light brush only).....	hours..	2

Cook No.	Liquor charge, initial concentrations.		Chemicals charged per 100 pounds of chips (bone-dry basis).		Initial volume of digester liquors per pound of chips (bone-dry basis).	Duration of cooking.		Yield of crude pulp (bone-dry basis).
	NaOH.	NaCl. ¹	NaOH.	NaCl. ¹		Total.	At maximum gauge pressure.	
	<i>Grams per liter.</i>	<i>Grams per liter.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Gallons.</i>	<i>Hours.</i>	<i>Hours.</i>	<i>Per cent.</i>
118	44.2	28.6	15.0	10.0	0.420	3.0	2.5	73.9
122	41.1	20.0	20.0	10.0	.600	4.0	3.5	63.5
128	49.2	12.0	20.0	5.0	.500	6.0	5.3	58.9
137	36.3	0	20.0	0	.662	6.0	5.3	58.9
72	35.2	0	20.0	0	.681	3.0	2.3	71.6

(P. L.—138, S. L.—176.)

¹ The values shown represent common table salt and not the pure chemical.

EFFECTS OF SULPHUR.

Cooks using "flowers of sulphur" and caustic soda as the cooking chemicals produced pulps almost identical with those resulting from the sulphate process. The addition of sulphur undoubtedly imparted to the pulps the resistance to wear and strength not obtainable by the soda process alone. These cooks, however, were characterized by the same disagreeable odor as the sulphate cooks, and this modification of the soda process seems to have no particular technical advantage over the sulphate process except in the matter of control of the cooking liquors.

EFFECTS OF VARYING THE PRESSURES OR TEMPERATURES OF COOKING.

In the sulphate process, as in the soda process, the digester pressures represent the pressure of saturated steam, since no other gases are present in sufficient quantity to affect the pressure. This

was determined by actual test. The digester pressures, therefore, correspond to the temperatures of saturated steam; and values of each may be converted into the other by means of standard steam tables.

Table 8 shows the effect on yield of variations of pressure from 40 to 140 pounds per square inch. As the pressures increased, the yields decreased. Cook 45, with a pressure of 40 pounds per square inch, resulted in a product so much undercooked that no pulp could be prepared from it. The yield, of course, was very high. Cook 46, using a pressure of 140 pounds per square inch, resulted in 50 per cent yield. For intermediate pressures the yields were correspondingly higher.

TABLE 8.—*Effect of varying pressures on the yield of pulp.*

Weight of chips charged (bone-dry basis).....	pounds...	1.000 to 1.005
Water in chips.....	per cent...	10.4 to 11.0
Causticity of liquor charge.....	do.....	53.5
Sulphidity of liquor charge.....	do.....	27.4
Initial volume of digester liquors per pound of chips (bone-dry basis).....	gallons...	0.667 to 0.680
Duration of cooking, total.....	hours.....	3.0
Duration of cooking at zero gauge pressure.....	do.....	0.1
Duration of cooking at maximum gauge pressure.....	do.....	2.0 to 2.3
Total duration of beater treatment (at light brush only).....	do.....	0 or 1

Cook No.	Liquor charge, initial concentrations.			Chemicals charged per 100 pounds of chips (bone-dry basis).			Maximum gauge pressure.	Yield of crude pulp (bone-dry basis).
	NaOH.	Na ₂ S. ¹	All sodium compounds as Na ₂ O.	NaOH.	Na ₂ S. ¹	All sodium compounds as Na ₂ O.		
	Grams per liter.	Grams per liter.	Grams per liter.	Pounds.	Pounds.	Pounds.	Pounds.	Per cent.
45	21.3	10.6	30.8	12.0	6.0	17.4	40	(?)
42	21.1	10.6	30.6	12.0	6.0	17.4	80	61.3
39	21.2	10.6	30.7	12.0	6.0	17.4	90	60.2
41	21.1	10.6	30.6	12.0	6.0	17.4	120	54.0
46	21.3	10.6	30.8	12.0	6.0	17.4	140	50.0

(P. L.—138, S. L.—3 b.)

¹ The same values apply to the Na₂SO₄ used.

² Wood not cooked; no pulp prepared.

Pulps produced with the higher pressures were stronger and had better wearing properties than those resulting from the lower pressures. With lower pressures the pulps became more and more brittle and gradually lost their soft, pliable, leather-like feel. The pulps resulting from the lower pressures were the more brown in color.

The best pressure conditions for these tests seemed to be from 100 to 140 pounds per square inch. If larger amounts of chemicals had been employed, pulps of the same yield and properties would probably have resulted from pressures of 80 to 100 pounds per square inch.

EFFECTS OF VARYING THE DURATIONS OF COOKING.

Since the time from the start of a cook until maximum pressure was obtained in the autoclave was practically constant (varying from 0.5 to 0.7 hour), only the total duration of cooking will be considered. Table 9 shows how the yields were affected for total durations varying from one to nine hours in three series of tests, using high, medium, and low amounts of chemicals. In the case of the first series, employing very high amounts of chemicals, 55.9 per cent of the wood (giving a yield of 44.1 per cent) was dissolved during two hours of cooking, while by cooking for seven hours longer an additional loss of only 12.8 per cent occurred. Cook 124, with a total duration of but one hour, afforded the best pulp and the highest yield for this series. This pulp came from the autoclave in the form of soft chips, and the resultant paper made from the beaten pulp was firm and strong, with good resistance to wear. The other pulps were soft and fuzzy, due to overcooking. As the duration increased, the color of the pulps changed from brown (cook 124) to light gray (cook 78).

TABLE 9.—*Effect of varying durations of cooking on the yield of pulp.*

Weight of chips charged (bone-dry basis),	pounds..	0.964 to 1.034
Water in chips,	per cent..	16.0 to 24.4
Causticity of liquor charge,	do.	51.6 to 53.3
Sulphidity of liquor charge,	do.	26.5 to 27.4
Initial volume of digester liquors per pound of chips (bone-dry basis),	gallons..	0.667 to 0.680
Duration of cooking at zero gauge pressure,	hours..	0.1
Maximum gauge pressure per square inch,	pounds..	90
Total duration of beater treatment (at light brush only),	hours..	1.5 or 2

FIRST SERIES.

Cook No.	Liquor charge, initial concentrations.			Chemicals charged per 100 pounds of chips (bone-dry basis).			Duration of cooking.		Yield of crude pulp (bone-dry basis).
	NaOH..	Na ₂ S. ¹	All sodium compounds as Na ₂ O.	NaOH.	Na ₂ S. ¹	All sodium compounds as Na ₂ O.	Total.	At maximum gauge pressure.	
	Grams per liter.	Grams per liter.	Grams per liter.	Pounds.	Pounds.	Pounds.	Hours.	Hours.	Per cent.
124	71.9	36.0	104.7	40.0	20.0	58.3	1.0	0.5	57.4
125	71.9	36.0	104.7	40.0	20.0	58.3	2.0	1.5	44.1
80	72.0	36.0	104.7	40.0	20.0	58.2	5.0	4.3	37.8
78	72.0	36.0	108.1	40.0	20.0	60.1	9.0	8.3	31.3

SECOND SERIES.

123	44.9	22.5	65.4	25.0	12.5	36.4	1.0	0.5	68.6
126	44.9	22.5	65.4	25.0	12.5	36.4	2.0	1.5	48.5
84	45.0	22.7	65.6	25.0	12.6	36.5	5.0	4.3	45.0
83	45.0	22.7	65.6	25.0	12.6	36.5	9.0	8.3	38.2

THIRD SERIES.

86	21.6	10.8	31.4	12.0	6.0	17.4	1.0	0.3	80.9
127	21.6	10.8	31.6	12.0	6.0	17.6	2.0	1.5	66.7
88	21.2	10.6	30.8	12.0	6.0	17.4	5.0	4.3	59.0
87	21.6	10.8	31.4	12.0	6.0	17.4	9.0	8.3	57.0

¹ The same values apply to the Na₂SO₄ used.

In the second series, when medium amounts of chemicals were used, prolonging the durations of cooking likewise resulted in decreasing the yields. The yield for cook 123, with a total duration of one hour, was 68.6 per cent; and cook 83, with a total duration of 9 hours, had a yield of 38.2 per cent. With a 2-hours' duration the amount of the wood dissolved was 51.5 per cent (48.5 per cent yield), while with a 7-hours' longer cooking period the loss was only 10.3 per cent additional. The best kraft pulps were obtained from cooks 126 and 84, with total durations of 2 and 5 hours, respectively. The resultant papers were firm and strong, and resistant to wear. Cook 123, using a duration of 1 hour, resulted in a weak, brittle, and undercooked pulp, while the pulp from cook 83, which had a duration of 9 hours, was soft, fluffy, and evidently overcooked.

The same general effects resulted from varying the durations in the third series of tests in which comparatively low amounts of chemicals were employed. In this case, however, the best pulps were produced with the longer durations, 5 hours for cook 88 and 9 hours for cook 87. The tests employing shorter durations resulted in weak and brittle pulps, due to undercooking. The pulp from cook 88 was slightly inferior to that from cook 87, but both would be considered of fair quality for making kraft wrapping paper.

The results from the three series of tests indicate that cooks employing high amounts of chemicals and very short durations will afford pulps of a quality and yield similar to those obtained when using medium amounts of chemicals and medium durations and to those resulting from the use of low amounts of chemicals and comparatively long durations. It is evident, however, that much more careful control of the operations must be exercised in order to obtain consistent results when high amounts of chemicals are employed.

EFFECTS OF VARYING THE INITIAL CONCENTRATIONS.

In each of two series of tests varying the initial concentrations of chemicals in the liquor charge the amounts of chemicals per 100 pounds of wood were held constant as follows: 15 pounds of caustic soda, 7.5 pounds of sodium sulphide, and 7.5 pounds of sodium sulphate for the first series, and 12 pounds of caustic soda, 6 pounds of sodium sulphide, and 6 pounds of sodium sulphate, for the second series. Since the amounts of chemicals were held constant, and the concentrations varied, the initial volumes of digester liquors per pound of chips also varied accordingly. Table 10 shows the effect of the varying concentrations on the yield of pulp.

TABLE 10.—*Effect of varying initial concentrations on the yield of pulp.*

Weight of chips charged (bone-dry basis).....	pounds..	0.964 to 1.031
Water in chips.....	per cent..	16.4 to 24.4
Causticity of liquor charge.....	do....	52.8 to 53.6
Sulphidity of liquor charge.....	do....	27.2 to 27.5
Duration of cooking, total.....	hours..	3.0
Duration of cooking, at zero gauge pressure.....	do....	0.1
Duration of cooking at maximum gauge pressure.....	do....	2.0 to 2.5
Maximum gauge pressure per square inch.....	pounds..	90
Total duration of beater treatment (at light brush only).....	hours..	2
Chemicals charged per 100 pounds of chips (bone-dry basis):		
NaOH.....	pounds..	First series. 15.0 Second series. 12.0
Na ₂ S.....	do....	7.5 6.0
Na ₂ SO ₄	do....	7.5 6.0
All sodium compounds as Na ₂ O.....	do....	21.8 17.5

FIRST SERIES.

Cook No.	Liquor charge, initial concentrations.				Initial volume of digester liquors per pound of chips (bone-dry basis).	Yield of crude pulp (bone-dry basis).
	NaOH.	Na ₂ S.	Na ₂ SO ₄ .	All sodium compounds as Na ₂ O.		
	Grams per liter.	Grams per liter.	Grams per liter.	Grams per liter.	Gallons.	Per cent.
89	60.0	30.0	30.0	87.2	0.300	47.9
90	45.0	22.5	22.5	65.1	.400	53.3
91	36.0	18.0	18.0	52.1	.500	55.2
93	30.0	15.0	15.0	43.6	.600	58.6
94	25.7	12.9	12.9	37.4	.700	61.3
95	22.5	11.2	11.2	32.7	.800	64.4
96	20.0	10.0	10.0	29.0	.900	66.4
97	18.0	9.0	9.0	26.1	1.000	66.9

SECOND SERIES.

112	72.0	36.0	36.0	104.9	0.200	51.0
100	49.7	24.8	24.8	72.0	.290	51.1
101	36.0	18.0	18.0	52.2	.400	52.3
105	28.8	14.6	14.4	42.2	.500	56.0
114	24.0	12.0	12.0	35.0	.600	62.6
106	20.6	10.3	10.3	30.0	.700	60.6
107	18.0	9.0	9.0	26.2	.800	66.0
108	16.0	8.0	8.0	23.3	.900	67.4
115	14.4	7.2	7.2	21.0	1.000	67.3
110	12.0	6.0	6.0	17.5	1.200	67.8
111	10.3	5.1	5.1	15.0	1.400	67.4

(P. L.—138, S. L.—176.)

When the concentration of all sodium chemicals expressed as Na₂O was varied from 26.1 to 87.2 grams per liter (first series of tests) the resultant yield decreased from 66.9 to 47.9 per cent. The best results, considering both yield and quality of pulps, were obtained from cooks 91 and 93, using Na₂O concentrations of 52.1 and 43.6 grams per liter, respectively. Pulps produced from cooks having lower concentrations were brittle and lacked strength and wearing properties. In the second series of tests, using somewhat smaller amounts of chemicals, the higher concentrations afforded the better results. The best pulp with regard to strength and wearing properties was that obtained from cook 112, using a Na₂O concentration of 104.9 grams per liter. The pulps obtained when using a concentration of 35 grams per liter or less were quite brittle, and had little strength and poor wearing properties.

SUMMARY OF CONCLUSIONS FROM THE AUTOCLAVE TESTS.

(1) The effective cooking chemicals in sulphate cooking liquors are caustic soda and sodium sulphide, the former being the more drastic in its action. Sodium sulphate and sodium carbonate, which unavoidably occur in the commercial liquors, are of no assistance in cooking, at least so far as the wood of longleaf pine is concerned.

(2) Increases in the amounts of either caustic soda or sodium sulphide, or both, result in more thorough cooking. The same effect may be obtained by increasing either the cooking pressure, the duration of cooking, or the initial concentrations of the chemicals in the cooking liquors.

(3) More thorough cooking is evidenced by decreased yields and by lighter colored pulps until a condition of very thorough cooking is reached, after which the color of the pulp is not affected.

(4) The best, or well-cooked, sulphate kraft pulps will have good strength and wearing properties, will be light brown in color, and will have a smooth, firm, leather-like feel when properly beaten. Undercooked pulps are characterized by a darker brown color, brittleness, lack of strength, and poor wearing properties. Overcooked pulps are light gray in color and may have good strength and wearing properties when properly beaten, but the yield will be low. Pulps much overcooked, in addition to being light gray in color, will be soft and fluffy, with little strength.

(5) With each different combination of the cooking conditions there is a definite minimum amount of sodium sulphide which must be used in conjunction with the caustic soda present to impart to the product the high strength and good wearing properties characteristic of properly cooked sulphate kraft pulps.

(6) The use of sodium chloride in conjunction with caustic soda improves the quality of the pulp to a slight extent only. The similar use of sulphur results in pulps having properties practically the same as those of sulphate pulps.

(7) As the proportion of sodium sulphide in the digester charge is increased, the disagreeable odor produced in the cooking operations becomes more pronounced.

PRACTICAL SIGNIFICANCE OF THE EXPERIMENTS.

While the present experiments are not complete, they show conclusively (1) that longleaf pine is well adapted for the manufacture of natural-color kraft pulps and papers; (2) that the sulphate process of pulp making applied to this wood affords products of better quality and of higher yields than the soda process; (3) that kraft papers can be made from longleaf pine equal or superior in quality to the imported and domestic kraft papers now on the market; and (4)

that the high gravity of the wood and the resultant high yield of pulp per cord give longleaf pine an advantage possessed by few, if any, other commercially important woods suitable for pulp making.

The autoclave tests indicate that there should be a certain combination of values for the variable cooking conditions which will result in the most economical method of operation. However, other factors than the variables thus far investigated must be taken into consideration in determining what this combination is. For example, the proper degree to which a pulp must be cooked will depend partly upon the cost of the beater treatment. With cheap power for beating, the pulp need not be so severely cooked as when the cost of power is high. The best concentrations and proportions of chemicals in the digester liquors will likewise depend upon the efficiency of the recovery system and the method of operating it.





BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE

No. 73



Contribution from the Bureau of Animal Industry, A. D. Melvin, Chief.

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RAISING AND FATTENING BEEF CALVES IN ALABAMA.¹

By DAN T. GRAY, *Formerly Professor of Animal Husbandry, Alabama Polytechnic Institute*, and W. F. WARD, *Senior Animal Husbandman in Beef Cattle Investigations, Animal Husbandry Division*.

STATEMENT OF FORMER WORK.

During the years 1906, 1907, and 1908 the Bureau of Animal Industry, working in cooperation with the Alabama Agricultural Experiment Station, conducted experiments in cooperation with Mr. J. S. Kernachan, of Sheffield, Ala., to obtain definite information regarding the cost of raising grade steers to the feed lot period under average southern conditions. (See Bulletin 131 of the bureau, or 150, Alabama Experiment Station.) The animals used in the Kernachan work were a herd of grade Aberdeen-Angus cows, headed by two pure-bred Aberdeen-Angus bulls. During the summer months the herd grazed upon a good pasture; no feed was given in addition to the pasture. This pasture was made up principally of white clover, Japan clover (*lespedeza*), several varieties of native grasses, and some Bermuda. This afforded the animals abundant pasture for about seven months of the year. During the winter all of the cattle, young and old, had the run of the range, which consisted of old corn and cotton fields, with some cane along the river and creek banks. In addition to the winter range, hay and cotton seed were fed, so that when spring came the cattle were in reasonably good flesh. The young stock made gains during the winter, but the cows and older animals usually lost in weight during the latter part of the winter. These cows and calves were allowed to become infested with the cattle tick, but when they became badly infested they were greased on those parts of the body where ticks were most numerous. The presence of the cattle tick, together with an outbreak of tuberculosis, caused the steers to be produced at an abnormally high figure, as the ticks no doubt materially retarded the growth of the steers and the

¹ The experiments reported in this paper were conducted in cooperation with the Alabama Agricultural Experiment Station.

NOTE.—This publication is of interest to farmers in the Southern States.

tuberculosis caused several deaths. Even when these two extremely unfavorable conditions are taken into consideration, the calves and steers were still produced at a profit. The authors state that—

When all the expenses, as deaths, rent on pasture, interest on money, etc., were charged against the animals and no credit was made for the manure, the expense of producing a steer varied from \$4.96 to \$5.25 per 100 pounds, as follows:

To 12 months of age, \$5.25 per hundredweight.

To 24 months of age, \$4.96 per hundredweight.

To 30 months of age, \$5.05 per hundredweight.

To 33 months of age, \$5 per hundredweight.

These figures mean that if the animals are sold for the above prices, the feeds used are marketed at a good farm price; all deaths are deducted; 7 per cent interest is received on the money invested in the animals; \$2.50 an acre is secured as rent for the summer pasture, and finally the manure is secured free.

DETAILS OF THE EXPERIMENT.

As noted above, conditions surrounding the previous herd were not entirely satisfactory, as the animals were infested with ticks and affected with tuberculosis, consequently the test reported in this bulletin was undertaken with a herd which was free from tuberculosis and was rapidly being made free from cattle ticks, as every animal on the farm was dipped in an arsenical solution every two weeks. No ticks were seen on the calves during the progress of the test.

OBJECTS OF THE WORK.

The principal objects of the work were:

(1) To learn what it would cost to raise a beef calf to an age of approximately 9½ months under average farm conditions.

(2) To determine the profit, if any, in finishing these young calves for the market during the winter months, and selling them when about 12 months old.

THE CATTLE USED.

The animals used in this work were a herd of grade Aberdeen-Angus, a few grade Shorthorns, and four or five native cows, headed by two bulls, one of which was a purebred Aberdeen-Angus, while the other one was a high-grade Aberdeen-Angus.

The owner of the herd, Mr. E. F. Allison, of Sumter County, Ala., with whom the work was conducted, began several years previously the work of grading up scrub cows which had been bought from some of the neighboring farmers. Consequently, when the herd was entered in this experimental work it was under normal conditions and consisted of individuals considerably above the average of the State. As far as breeding and quality were concerned the Kernachan and Allison herds were very similar. The cows in both tests were small, those in the Sumter County experiment averaging only 630 pounds in weight February 9, 1911. However, at this time of the year they were poor and were in their lightest form. In the fall of the

year, before losing any of their normal summer weight, they averaged perhaps 800 pounds in weight. It will be seen later that these small cows raised calves which attained an average weight of 560 pounds by the time they were 12 months old. The Kernachan cows averaged about 830 pounds in weight at the end of the winter, but the calves from these larger cows were undersized, due largely, perhaps, to the presence of the cattle tick. As a result of the use of good bulls, the calves obtained from these grade cows were, as a rule, good ones. They were in the first place much larger than the average calves of the State, and in the second place measured up much more closely to the ideal beef conformation than calves obtained from native cows.

MANAGEMENT OF THE HERD.

The cows were bred so as to have the calves dropped during the spring months. During the summer months the animals, both young and old, grazed upon a moderately good pasture; no feed except salt was given in addition to the pasture. During these pasture months the cows ate nothing but pasture grasses while the calves had the cows' milk in addition to the grasses. The main pasture was made up principally of Japan clover and broom sedge, which had come naturally after the clearing of the land. This large pasture consisted of approximately 1,000 acres, but a very large part was covered with trees; under these trees the ground was bare. A small adjoining pasture of approximately 30 acres had been partly set to Bermuda, but this was used only occasionally for some calves. These permanent pastures afforded the animals reasonably good grazing for about six months of the year.

When the pastures became exhausted in the late fall the calves were weaned, the males castrated, and the cows and calves placed in separate fields and fed and managed differently. The cows were placed in the old corn and cotton fields, thus being fed the rough feeds of the farm along with small amounts of cottonseed cake. The calves were prepared for the winter fattening period. The following short statements give a brief history of the management of the cows and the lives of the calves from January 1, 1911, to April 1, 1912:

(1) The calves were born during the months of January, February, March, and April in 1911. The majority were born in March and April. At this time the cows were running in a field of 640 acres which had a small growth of cane; a part of this field consisted of old corn and cotton fields.

(2) The cows ate nothing except the cane and what roughage they secured from the old corn and cotton fields until January 23. By this time the rough field feeds had been pretty well consumed, consequently a small daily feed of cottonseed cake was introduced to supplement the range. The feeding of cottonseed cake was continued until April 14. On this date the cows and calves were all turned into the large

permanent pasture, and the ration of cottonseed cake was fed until May 7, as the season that year was exceedingly unfavorable for the early growth of pasture grasses.

(3) During the summer months the cows and calves ran together in the large pasture.

(4) The cows and calves were separated September 25. The calves were placed in a field containing old cornstalks, crab grass, and cowpeas. They remained in this field until October 7, when they were transferred to a field of peanuts which were to be subsequently grazed off by hogs. This peanut field afforded grazing until October 16 when they were returned to the corn and cowpea field. They were kept in this field until November 24, but were fed a small amount of cottonseed cake in addition, beginning with 1 pound of cake per calf per day on October 28 and gradually increasing the amount to 2 pounds. By November 24 the supply of feed in this field was exhausted, so the calves were transferred to a third field of cornstalks and crab grass, where they remained until the fattening period was inaugurated.

(5) By December 21 all of the available rough feeds of the farm had been consumed, and the calves were placed in a small barn lot and fattened for the early spring market. During this fattening period they were fed cottonseed meal, corn silage, and a cheap quality of broom-sedge hay.

(6) The calves were shipped to New Orleans and sold April 1, 1912.

(7) The bulls were allowed to run with the cows the year round. This, however, was found to be a poor practice, as the date of calving could not be regulated. When the bulls are with the cows continuously the first calves come too early in the season, and the last calves come too late. It is a much better practice to keep the bulls away from the herd of cows all the time except during the usual and proper breeding season.

PRICES AND CHARACTER OF FEEDS.

Cottonseed meal, cottonseed cake, pastures, corn silage, and broom-sedge hay were all used in the test. Cottonseed meal, corn-silage, and the hay were fed to the calves during the fattening period. The cows during the winter of 1911-12 were not given silage, as the supply was limited, but there is no doubt that both the cows and the calves would have done much better if the cows had been given a liberal quantity of this succulent feed. All of the feeds except the broom-sedge hay were of good quality. The cottonseed meal and cottonseed cake were fresh and bright. The corn silage was also of excellent quality; it was made of corn which would have yielded about 30 bushels of grain to the acre. While the hay was bright, clean, and well cured, it was of exceedingly poor quality, as broom sedge will not make a good quality of hay. It is, however, a roughage that should not be wasted.

In work of this character the financial statement is not as exact as might be desired, because the price of feeds, as well as of cattle, fluctuates considerably from year to year. The financial outcome of a particular experiment may not be duplicated by the cattle raiser or feeder, owing to the different conditions under which he is operating. The prices listed in this bulletin were the actual prices paid for the feeds (except corn silage and broom-sedge hay, which were made on the farm) and the actual prices realized for the cattle. This test was conducted during the winter of 1911-12; prices have not changed materially since that time. The following were the



FIG. 1.—SOME OF THE COWS OF THE BREEDING HERD. THEY WERE GRADE ABERDEEN-ANGUS, THOUGH PART OF THEM ALSO HAD SOME SHORTHORN BLOOD.



FIG. 2.—ANOTHER VIEW OF SOME OF THE CATTLE USED IN THE EXPERIMENT TO DETERMINE THE COST OF RAISING CALVES IN ALABAMA.



prices of the feeds, those of corn silage and hay being estimated: Cottonseed meal and cottonseed cake \$26 a ton, corn silage \$3 a ton, and broom-sedge hay \$5 a ton.

METHOD OF CONDUCTING THE WORK.

The herd was kept and fed under average farm conditions. E. F. Allison, a farmer and stockman of Sumter County, Ala., agreed to cooperate, and the feeding was all done upon his farm. Mr. Allison furnished the cattle and the feed, while the work was planned and the feeding carried on under the supervision of the authors of this bulletin. E. R. Eudaly was stationed as assistant on the farm and had personal supervision of the experiment.

No barns or other artificial shelter were provided for the cows. During the winter months they were in fields where trees, together with the underbrush, afforded ample protection for mature animals. The calves, however, were provided with excellent shelter during the winter. While being fattened they were inclosed in a small lot in which was a good barn. The doors were always open so that they could go in and out at will. They were fed twice each day in troughs placed under the extending eaves of the barn. The calves were fed in such amounts that the feed was all eaten within a short time after it was put before them. An abundance of pure water and salt was provided all the time.

At the close of the test the calves which had been fattened were sold and shipped to New Orleans. The experimental farm was located 4 miles from Bellamy, Ala., the nearest railroad station, and the animals were driven to that point to be loaded on the cars.

THE EXPENSE OF RAISING THE CALVES TO WEANING TIME.

As previously stated, the majority of the calves were born in March and April. During the winter months the cows grazed the old corn and stalk fields and some "switch" cane which grew along the banks of a small stream. Beginning January 23, or immediately after the first cows dropped calves, the cows were given some cottonseed cake each day. As the grass was slow to establish itself in the spring of 1912 it was necessary to continue feeding the cows a small amount of cake until May 7. During the period from January 23 to May 7 the 80 cows consumed 6,390 pounds of cottonseed cake in addition to the feed they secured from the winter range and the early pastures. This was an average daily feed of a little less than 1 pound of cake for each cow, as they were fed for a period of 104 days. The cows were wintered in an unusually economical manner, and the farmer who lives on an average Alabama farm must expect to use more feed than was given to these cows, as the average farm at the present time has only a small acreage of old corn and cotton fields. It

was these fields which made it possible to get the cows through the winter in such a cheap manner.

The calves were not put in the fattening lot at the date of weaning, September 25. It had been planned to graze two or three fields by them before the finishing period arrived; consequently, as soon as they were taken from the cows, they were placed in a 50-acre field containing cornstalks, crab grass, and cowpeas. The peas had been planted at the last cultivation of the corn. The calves remained in this field until October 7, when they were transferred to a field of peanuts, which had been grown for hogs; they were taken to this field to graze off the tops of the peanuts. This small field afforded grazing for nine days, or until October 16, when the calves were taken back to the first field of old cornstalks and peas, where they were kept until November 24. This field did not, however, afford sufficient feed to produce gains, so on October 28 it was decided to add cottonseed cake. The cake was introduced at the rate of 1 pound per calf daily and gradually increased to 2 pounds. The 50-acre cornfield was so completely grazed by November 24 as to provide no further feed, so the calves were transferred to a second field of cornstalks, cowpeas, and crab grass, which had been saved for them. They remained in this second field, all the while eating 2 pounds of cottonseed cake per calf per day, until December 21, when they were taken to the barn, shut up in a small lot, and started on a preliminary ration of cottonseed meal, corn silage, and broom-sedge hay. By January 17 they were all accustomed to the new ration, and the fattening period was inaugurated. On this date they averaged approximately $9\frac{1}{2}$ months of age. The following brief statement gives a short summary of the important facts of the cost of raising these calves to $9\frac{1}{2}$ months of age:

Cost to raise calves to an age of $9\frac{1}{2}$ months.

To 6,390 pounds of cottonseed cake eaten by the cows from Jan. 1, 1911, to Jan. 1, 1912, at \$26 a ton.....	\$83. 07
To pasture rent for whole herd of 80 cows.....	250. 00
To taxes on \$2,380 invested in cattle.....	4. 60
To interest on \$2,380 invested in cattle, at 6 per cent.....	142. 80
To 4,750 pounds of cottonseed cake fed calves in November and December...	61. 75
To 3,425 pounds of cottonseed meal fed calves Dec. 21 to Jan. 16.....	44. 53
To 24,035 pounds of silage fed calves Dec. 21 to Jan. 16.....	36. 05
To labor devoted to cattle during year.....	58. 50
To 10 per cent depreciation in value of breeding cattle.....	238. 00
Total cost of 64 calves to $9\frac{1}{2}$ months' of age.....	919. 30
Average weight of each calf Jan. 16, 1912..... pounds..	460
Average cost of each calf.....	\$14. 36
Average cost per hundredweight.....	3. 12

In studying the above financial statement the reader should understand that the cost of raising calves varies very materially from place

to place. They were raised to an age of $9\frac{1}{2}$ months on this farm at a cost of \$3.12 a hundredweight. On a second farm it may cost more, and on a third it may cost less. Each item noted above may not be duplicated upon another farm. The pasture rent, the taxes, the interest, the prices of feeds, and the cost of labor all vary in different localities.

When these calves had reached an approximate age of $9\frac{1}{2}$ months they had attained an average weight of 460 pounds. While this is not a heavy weight, still it is much greater than that usually attained by native Alabama calves. In the experimental work carried on in cooperation with Mr. Kernachan, of Sheffield, Ala., the calves, at 12 months of age, had reached an average weight of only 402 pounds. Those calves, however, were infested with cattle ticks, which no doubt very materially impeded the rate of growth.

By the time the calves had reached an average age of $9\frac{1}{2}$ months, each one had cost \$14.36, or \$3.12 per hundredweight. These figures include the cost of all the feeds which were given to both the cows and the calves, the rent on the pasture, the taxes, and interest on the money invested in the cattle, the labor required to care for and feed both the cows and the offspring, and 10 per cent depreciation in value of the breeding herd. The cattle were not credited with the manure produced, as there was no way to determine this factor accurately.

THE FATTENING PERIOD.

The calves were raised to the fattening period, at a cost of \$14.36 each. On that date they had attained an average weight of 460 pounds, so it cost \$3.12 a hundredweight to raise them. They were consequently entered in the fattening period at an initial cost of \$3.12 per hundredweight.

There was a total of 64 calves in the herd, but all of them were not fattened for the market. The owner wished to build up the breeding herd, so 15 of the best heifers were kept on the farm. The remaining 49 calves were placed in the feed lot and given a ration of cottonseed meal, corn silage, and broom-sedge hay. The 15 heifers which were left on the farm were valued at \$15 each. This figure is incorporated later in the financial statement as a credit to the increase in value of the herd.

The fattening period proper began January 17, 1912, although the calves had been on a ration of cottonseed meal, corn silage, and broom-sedge hay since December 21. A short time was necessarily required to get the animals accustomed to their new feeds. The cost of the feeds they ate during the preliminary period from December 21 to January 17 was charged against the cost of raising the calves, and not against the cost of fattening. At the beginning of the test

proper each calf was eating daily 3 pounds of cottonseed meal, approximately 20 pounds of corn silage, and 4 pounds of hay. The allowance of meal was raised gradually throughout the whole period of 76 days, until at the last each calf was eating 6 pounds daily. At one time each calf was consuming as much as 28 pounds of silage each day, but they would not continue to eat this much, so at the end of the period, April 1, they were eating an average of only 20 pounds per calf per day. The allowance of hay was gradually decreased from the first. At the middle of the period each calf consumed daily not over 3 pounds of hay, and near the end an exceedingly small allowance met their desires. From the middle of March to April 1 they averaged less than 1 pound of hay per calf per day.

The fattening period continued for a period of 76 days, or until April 1, when the 49 calves were sold and then shipped to New Orleans. They brought \$5.87½ a hundredweight on the farm.

The following gives a short summary of the most important results obtained during the fattening period:

The fattening period (Jan. 17-Apr. 1).

Number of calves in lot.....	49
Number of days fed.....	76
Average initial weight.....pounds..	456
Average final weight.....do.....	560
Average total gain of each calf.....do.....	104
Average daily gain.....do.....	1.37
Average daily ration per calf:	
Cottonseed meal.....do.....	4.4
Corn silage.....do.....	23.9
Hay.....do.....	2.76
Amount of feed required to produce 100 pounds of gain:	
Cottonseed meal.....do.....	323
Corn silage.....do.....	1,741
Hay.....do.....	201
Cost to make 100 pounds of gain.....	\$7.31
Profit on each calf as a result of fattening.....	8.88
Initial cost of calves per hundredweight.....	3.12
Selling price on the farm per hundredweight.....	5.87½

As previously stated, it cost \$3.12 per hundredweight to raise these calves to an age of 9½ months, and they were valued at this figure at the inauguration of the finishing period. At the end of the fattening period they sold for an average price of \$5.87½ per hundredweight on the farm and made a clear profit of \$8.88 per calf.

The average weight of the calves at the beginning of the fattening period was 456 pounds. When sold, April 1, they had attained an average weight of 560 pounds and were approximately 1 year old. During this period they gained at an average daily rate of 1.37 pounds.

The only purchased feed used in the fattening period was cottonseed meal. The other two feeds, corn silage and broom-sedge hay, were made on the farm, the silage being valued at \$3 a ton and the cheap hay at \$5 a ton. Before a farmer spends \$26 for a ton of cottonseed meal he should know whether or not he will get his money back in the shape of profit on the cattle. On this particular farm the two feeds, corn silage and hay, were produced at home, and the object was to find a profitable market for them. While the cottonseed meal cost \$26 a ton, it was fed to the calves and sold, by means of them, for \$78.64 a ton. The corn silage was valued at only \$3 a ton, but it was sold by means of the calves for \$12.74 a ton in this particular test. An abnormally high price was realized on the hay because only a small amount was used.

The authors do not claim that such favorable results can always be secured, but these results, taken together with those previously secured during the progress of the beef investigational work in Alabama, show that the farmer can usually well afford to buy certain commercial feeds for his animals, and it is usually to his advantage to feed the home-grown feeds to live stock rather than sell them on the market.

RAISING AND FATTENING PERIODS TAKEN TOGETHER.

The following gives a brief outline of the whole life of the calves; this comprises both the raising and the finishing periods, and includes a full statement of the total expense of both the cows and the calves:

Total summary.

Number of cows in herd.....	80
Number of breeding bulls in herd.....	2
Number of calves raised.....	64
To pasture rent for whole herd.....	\$250.00
To taxes on \$2,380 invested in herd.....	4.60
To interest at 6 per cent on \$2,380 invested in herd.....	142.80
To 6,390 pounds of cottonseed cake fed to breeding cows during January, February, March, and April.....	83.07
To 4,750 pounds of cottonseed cake fed calves in November and December.....	61.75
To 3,425 pounds of cottonseed meal fed calves from Dec. 21 to Jan. 16.....	44.53
To 24,035 pounds of silage fed calves from Dec. 21 to Jan. 16.....	36.05
To 16,600 pounds of cottonseed meal fed calves from Jan. 17 to Apr. 1.....	215.80
To 89,545 pounds of corn silage fed calves from Jan. 17 to Apr. 1.....	134.32
To 10,377 pounds of broom-sedge hay fed calves from Jan. 17 to Apr. 1.....	25.94
To labor devoted to cattle during the year.....	58.50
To 10 per cent depreciation of the value of the breeding cattle.....	238.00
Total expenses of herd.....	1,295.36
Average cost of each calf when 1 year old.....	\$20.24
Average weight of each calf when 1 year old.....pounds..	560

Average cost, per hundredweight, to raise and fatten calves.....	\$3. 61
Amount of money received for 49 fat calves.....	1, 506. 55
Value of 15 heifers left on farm for breeding.....	225. 00
Total income of herd during 1911-12.....	1, 731. 55
Total profit on herd during 1911-12.....	436. 19
Average profit on each calf (64 calves).....	6. 81
Average profit on each cow (80 cows).....	5. 45

The herd consisted of 80 cows, but only 64 calves were raised to an age of 1 year; this is, however, an excellent record. This is much better than the results reported on the Kernachan herd, when only 70.8 per cent and 72 per cent of the cows dropped calves during the springs of 1906 and 1907, respectively. The breeder can not expect every cow in the herd to drop a calf each year. It is important, however, that as many of the cows as possible produce calves each year; the idle cows are not only idle capital but they are constant consumers of farm products. The idle cow has a very important part to play in the total expense of raising a calf, as an expense of keeping her must be charged against the calves which other cows produce. To illustrate: The above table shows that a clear profit of \$6.81 was made on each one of the 64 calves, but when the total number of cows was taken into consideration it is seen that a clear profit of only \$5.45 was realized on each.

It cost \$1,295.35 to care for and feed the whole herd during one year's time. This figure includes all possible expenses, as cost of labor, interest on investment, depreciation in the value of the herd, cost of pasture and all other feeds, and taxes. Forty-nine fat calves were sold for \$1,506.55; 15 good heifer calves were kept on the farm for future breeding purposes, and they were valued at only \$15 each. When the value of these 15 calves, \$225, is added to the sum received for the fat calves, the total income of the herd is raised to \$1,731.55. A total profit of \$436.19 was consequently realized on the whole herd of 80 cows.

These results are, of course, entirely satisfactory, as they represent profits above the interest on the money invested, while the value of the manure made on the farm is not taken into consideration. The worth of the manure should never be neglected but there was no way to determine the exact amount produced and no approximation was made.

SUMMARY STATEMENTS.

(1) The objects of this test were, first, to learn what it would cost to raise beef calves to an age of approximately 9½ months, under average farm conditions, and, second, to determine the profit, if any, in finishing these young calves for the market during the winter months and selling them when about 12 months old.

(2) A herd of 80 cows, mostly grade Aberdeen-Angus, were employed. From this herd 64 calves were raised during the year 1911.

(3) The calves were born during the spring months and ran with their mothers on pasture until late fall, when they were weaned and prepared for the fattening period, which was inaugurated on January 17, 1912, and continued until April 1, 1912.

(4) In all, there were 64 calves, but only 49 of these were fattened for the market. The owner wished to build up the breeding herd, so 15 of the best heifers were kept on the farm for future breeding.

(5) When the calves were $9\frac{1}{2}$ months old the 64 had attained an average weight of 460 pounds.

(6) It cost \$14.36 to raise each calf to an age of $9\frac{1}{2}$ months. This cost includes all possible expenses, or cost of all feed eaten by both cows and calves, interest on money invested in cattle, rent on pastures, taxes, depreciation on the value of the herd, etc. The average cost per hundredweight was \$3.12.

(7) Forty-nine of the 64 calves were then placed in the feed lot. These 49 animals averaged 456 pounds in weight at the beginning of the fattening period and 560 pounds at the close. They, therefore, gained at the average daily rate of 1.37 pounds.

(8) Each calf, during the fattening period, ate daily 4.4 pounds of cottonseed meal, 23.9 pounds of corn silage, and 2.76 pounds of broom-sedge hay.

(9) To make 100 pounds of increase in live weight required the use of 323 pounds of cottonseed meal, 1,741 pounds of corn silage, and 201 pounds of hay, costing \$7.31.

(10) When the calves were fat they were sold on the farm for \$5.87½ a hundredweight. It cost only \$3.61 per hundredweight to raise and fatten them.

(11) The total profit on the herd during 1911-12 was \$436.19 or an average of \$6.81 for each calf.





BULLETIN OF THE U.S. DEPARTMENT OF AGRICULTURE



No. 74

Contributed by the Bureau of Crop Estimates, L. M. Estabrook, Chief,
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INLAND BOAT SERVICE: FREIGHT RATES ON FARM PRODUCTS AND TIME OF TRANSIT ON INLAND WATERWAYS IN THE UNITED STATES.

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PURPOSE AND SCOPE OF INQUIRY.

The purpose of this inquiry was to collect information relative to freight rates and time of transit of farm products carried on inland waterways of the United States. It being impracticable to collect complete data, the inquiries were made to cover a large number of representative routes and commodities. The freight rates apply to September and October, 1912, when a large part of the agricultural products of 1912 was moving to market and, naturally, traffic on waterways would be relatively large. The freight rates by boat were obtained directly from captains, agents, and other officials of steamboat lines. Some reports for distances were also obtained from these persons, but mostly from the Chief of Engineers of the United States Army, who has charge of the improvement of waterways. For minor items and for verification other sources were used; they included notes made by the author at various times in the course of field work, information received through correspondence, and data gathered from various printed matter.

RIVER TRAFFIC DEFINED.

River traffic as discussed in this bulletin is to be distinguished from the traffic by coastwise vessels and on the Great Lakes. Conditions are different in many respects between the river transportation and that conducted by the large vessels on deep water. One point of difference lies in the size of the river boats as compared with the lake and coastwise vessels. A large freight steamer on the Great Lakes will carry as much as 400,000 bushels of wheat at one load. On June 30, 1912, the average gross tonnage of vessels on the Great

Lakes was 876 tons of 100 cubic feet, while the average for vessels on the western rivers was only 78 tons measurement. The carrying capacity of river steamboats is increased by the use of barges. This is especially true in the shipment of coal from the Pittsburgh region to New Orleans. From 30 to 50 or more barges, each carrying about 1,000 tons (of 2,000 pounds), may be moved by a single towboat. In ordinary river freight service, one or more barges may be taken, especially when a lot of lumber or brick is to be carried. The use of a large number of barges is not practicable in the Great Lakes or the coastwise traffic, because the rough water would make it difficult, if not impossible, to handle them. Towing is done on the Lakes and ocean, but the vessels towed are larger in size than the river barges and only a few are taken at a time.

RELATIVE IMPORTANCE OF RIVER TRAFFIC.

The relative importance of receipts by river as compared with the total receipts by rail and water of various farm products at leading river ports is shown in Table 1. A considerable fraction of the wheat and corn received at Baltimore, Md., comes from landings along rivers which are tributary to Cheapeake Bay and is carried partly by steamboats and partly by sail vessels. During the five years ending with 1912 these receipts by water at Baltimore ranged from 10 to nearly 30 per cent of the total receipts of wheat and from 3 to nearly 15 per cent of the total receipts of corn.

Cincinnati, Ohio, also has a large river trade in some products, notably tobacco. Of the total receipts of tobacco during the five years ending with 1908, from 10 to 20 per cent came by river boats. This applies to tobacco packed in hogsheads, which formed all but a small fraction of the traffic in that commodity. For other articles the relative importance of the river trade was not so great. During the five years mentioned about 5 per cent of the total receipts of eggs were brought in by steamboat. Apple receipts averaged from about one-third of 1 per cent of the total to more than 12 per cent. Relatively little of the grain brought to the city came by river, the average being considerably less than 1 per cent of the total. In regard to live stock, the river traffic in cattle constituted 1 to 2 per cent in each of the five years in question, while for sheep the average was between 2 and 3 per cent, and for hogs the average was about 4 per cent of the total receipts from all sources. Statistics of the river trade at Cincinnati have been given by the Cincinnati Chamber of Commerce for a long series of years, extending back at least as far as 1845. These statistics show the river trade when it constituted practically all of the commercial movements to and from Cincinnati, except produce hauled in wagons and live stock driven on foot; and

they trace the development of railroad traffic, together with the relative and the absolute decline of transportation by river.

One of the principal items in the freight received at St. Louis by boat is apples, which are brought in large quantities from Calhoun County, Ill. This county, consisting of a long strip of land bounded on three sides by the Mississippi and Illinois Rivers, has no railroads and depends upon river boats for transportation. In 1911, 54 per cent of the barreled apples received at St. Louis came by river, and in 1912 the river receipts exceeded 49 per cent of the total receipts by all routes. Also, from 2 to 5 per cent of the eggs, from 4 to nearly 7 per cent of the cotton, from $1\frac{1}{2}$ to 2 per cent of the sheep, and from $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent of the hogs received at this city in 1908-1912 came by water.

Statistics of river trade at Memphis and New Orleans show relatively large receipts of cotton. At Memphis, during the five years ending with 1912, from 10 to nearly 14 per cent and at New Orleans from nearly 4 to more than 7 per cent of all cotton received was carried by boat.

MARKET VALUES OF PRODUCTS TRANSPORTED BY WATER.

Another basis of estimating the importance of steamboat traffic is the market value of products carried. The following approximate valuations are based upon average market prices at the respective cities where the produce was received, and are to be regarded merely as rough estimates. The wheat received by boat at Baltimore during the five years ending with 1912, at average prices of southern wheat, contract grade, was worth from \$600,000 to \$2,000,000 a year, and the corn receipts ranged from about \$200,000 to \$1,000,000, according to the prices paid for southern white corn.

At Cincinnati the receipts of tobacco by river averaged from \$1,500,000 to more than \$3,000,000 a year in 1908-1912; the cattle, hogs, and sheep were worth, at average prices, about \$750,000 to \$1,250,000 per year, while the eggs brought in by boat averaged \$150,000 to \$250,000.

Among the receipts at St. Louis during 1908-1912 whose value illustrates the importance of river traffic are apples, with an average annual value (disregarding the abnormally low receipts of apples in 1910) of about \$125,000 to \$775,000; eggs, worth \$150,000 to \$200,000 a year; cattle, sheep, and hogs, \$1,500,000 to \$2,000,000; and wheat, \$200,000 to \$500,000.

The annual receipts of cotton by river averaged \$5,000,000 to \$7,500,000 at Memphis and \$3,000,000 to \$7,000,000 at New Orleans in the five years just mentioned. Large quantities of other farm products were also received by river at these two cities.

SOME ADVANTAGES OF RAIL OVER RIVER.

While steamboat transportation is generally regarded as cheaper than rail, in practice the boats are at considerable disadvantage in some respects. A railroad car is free to move between any two railroad stations, while the steamboat is naturally limited to those places which it can reach. At terminals a car can be placed in any one of a number of advantageous positions. A car of wheat can be run into a grain elevator and unloaded over a grating, through which the grain is received by the elevating machinery and carried to the bins. A railroad car also may be placed alongside any one of a number of warehouses, to receive or discharge its load across a few feet of space; and it may be held for a day or so, if not longer, awaiting a convenient time for consignor to load or for consignee to unload. In regard to rates, as will be shown later, the steamboats do not always quote lower rates than are quoted by railroads.

SOME ADVANTAGES OF RIVER OVER RAIL.

Since the river is a public highway, there is an opportunity for competition among carriers which does not exist with rail traffic. In railroad business the roadway and terminals are regularly under the same management as the trains which use them, so that competition between two or more carriers over a single railroad is not to be expected. The fact that the river is a public highway makes it possible for persons of small capital to engage in transportation. Consequently sail vessels, gasoline launches, and small steamboats compete with larger boats for the traffic on many inland waterways. Sweet potatoes, watermelons, grain, and other commodities are brought into Washington and Baltimore from points from 100 to 200 miles distant by means of sail vessels and power boats. A considerable part of the produce sold at New Orleans is brought there by small boats, and on the river system opening into San Francisco Bay gasoline launches, sailboats, and other small vessels also share with the regular steamboat lines in the carrying trade. The opportunity offered to persons or companies of small capital to engage in transportation is one of the advantages of river over rail. These public waterways are used also by farmers to transport their own produce to market.

Another advantage of the river is the economy possible in a large part of the traffic, especially where relatively nonperishable articles are carried. The capacity of a boat can be increased or diminished greatly by attaching or detaching barges, so that a large load can be moved at a relatively low cost. In a large part of its business a boat can work much more cheaply than a railroad.

Frequently river transportation is quicker than rail. A consignment once loaded on a boat goes direct to its destination without being subject to delays occasioned by transfer from one carrier to

another or from the switching of cars. This applies, of course, only to shipments between points reached by the same boat and is true more for less-than-car-lot than for car-lot shipments. A carload carried by rail necessarily moves to its destination much more promptly than a small lot, which may have to be transferred from car to car in transit and possibly held for some days at various transfer points. The small lot moves as rapidly as the large one when shipped by boat, and, while the freight rate by boat is often lower for the large shipment than for the small, the difference between the two rates is usually not so great as it is in railroad traffic.

TERMINALS AND LANDINGS.

One striking difference between river traffic along the Atlantic slope and that in the Mississippi Valley is the different kinds of landings. On the tidal waterways of the Atlantic slope conditions require wharves to be built to enable boats to land and freight to be handled. This requirement naturally limits the landings to such places as regularly have traffic enough to justify the expense of building such a wharf. In the Mississippi Valley wharves are not only unnecessary for purposes of landing but are practically impossible to locate properly. The boat makes a landing by simply running alongshore and letting down the outer end of the landing stage, so that any part of a river bank which has no unusual obstruction may be taken as a landing. The great difference between the highest water level and the lowest and the uncertainty of the rise and fall of the river make it practically impossible to use fixed wharves at the river landings of the Mississippi Valley. However, wharf boats are established at principal landings and serve the purpose of a fixed wharf; and, since they rise and fall with the water level, they are in the right position to receive a steamboat alongside at any stage of the river.

The conditions which enable steamboats to stop at almost any unobstructed part of the bank make it possible for many farms on navigable rivers like those of the Mississippi Valley to have their own landings. On some rivers the landings actually used by steamboats are scarcely a mile apart, so that the entire country within hauling distance of the river has a large number of shipping points from which to select.

Convenient means of transfer between boat and rail are arranged at some terminals and at some intermediate landings as well. Railroad tracks, in some cases, are laid convenient to the steamboat landings and mechanical devices are used to facilitate transfer of freight from one carrier to another. There are many instances, of course, wherein improvement in transfer facilities is much needed, where the railroad tracks are inconveniently distant from the steamboat landing, and where few or no mechanical devices, other than

hand trucks, are used to facilitate handling of freight. In fact, most of the freight handled by rail or water is loaded and unloaded by means of hand trucks. Motor trucks for unloading or loading are found only in rare instances, but devices for assisting hand trucks up or down inclines and for moving heavier weights from one level to another are frequently used. At Riverton, Ala., an incline was built on the bank of the Tennessee River for the operation of a car by means of a steam-driven cable. This elevator transferred freight between the boats on the river and the railroad freight station up on the cliff. At any stage of the river this incline, of course, could be used, since it extended from the freight shed at the top of the high river bank to the lowest water level.

TYPICAL STEAMBOAT ROUTES.

ATLANTIC COAST.

The actual routes followed by steamboat lines in various parts of the United States have certain characteristics which differ according to location. The Hudson River has a variety of traffic. One class consists in the through service between New York City and Albany; another class of traffic is composed of numerous routes centering at various important cities along the way; and the canal-boat traffic on the way from the Erie Canal to tidewater, the boats being towed in groups each by a single tug. Among the farm products carried on this important waterway are grain, hay, fruit, and vegetables. Large quantities of wheat and corn are carried in canal boats on this river down to New York Harbor, the grain having been loaded at Buffalo.

Another important system of waterways is that of Chesapeake Bay and its tributaries. Traffic on this bay radiates from the principal cities—Baltimore, Washington, and Norfolk. The usual local steamboat trip from Baltimore begins late in the afternoon, the boat reaching the mouth of some river early the following morning, possibly some hours before daybreak. Here the first landing is made, which is followed by other landings up to the head of navigation. After a few hours at the terminus the boat starts on its return trip, often reaching the mouth of the river and entering Chesapeake Bay by nightfall and arriving at Baltimore early the next morning. This applies to a route of average length and of average distance from Baltimore. Some of the longer routes require 40 or more hours for transit one way, and on some of the shorter ones the round trip is made within a day. A great variety of produce is carried on these Chesapeake Bay routes. Grain, hay, and many kinds of fruits and vegetables constitute a large amount of traffic. From the lower part of the eastern shore of the bay sweet potatoes are shipped in such large quantities in the fall that they often make practically full

cargoes for the steamboats. Among other farm products received by water at Baltimore are tobacco from Patuxent River landings, live stock from the upper Rappahannock, and poultry and eggs from practically all the river routes.

Through service between Baltimore and Norfolk, Baltimore and Philadelphia, Norfolk and Washington, and between Norfolk and Richmond is maintained throughout the year by regular lines of boats. Over each of these routes the trip is made in a single night and the schedules are maintained as regularly as on railroads.

An important feature of Chesapeake Bay trade, as of some other waterways, is the large number of small craft, such as sail vessels, power boats, and small gasoline launches, which serve as common carriers on these waters. Early in July Baltimore Harbor swarms with such vessels bringing in the first of the wheat crop from the lower bay. They also carry a considerable amount of canned goods, water-melons, sweet potatoes, and other agricultural products. Their traffic in oysters, fish, lumber, railroad ties, and firewood is important also.

South of Virginia the Atlantic plain becomes wider and the navigable rivers extend farther inland, thus affording a wider reach from the coast for steamboat traffic than is afforded farther north. Steamboat traffic here begins to differ somewhat from the traffic on tidal waters and shows some points of resemblance to that of the Mississippi Valley. The long route from Baltimore to Fredericksburg, 285 miles, is not directly inland, but extends more than halfway parallel to the coast, the Rappahannock River itself measuring but 106 miles from its mouth to Fredericksburg; but from Savannah to Augusta the 202-mile route extends inland, as does the 370-mile route from Brunswick up the Altamaha and Ocmulgee Rivers to Macon.

Two isolated routes in the Atlantic coast region are worthy of mention. Lakes Champlain and George afford a highway for local traffic along part of the borders of Vermont and New York; and at the southern part of the Atlantic slope the Kissimmee River, with Lakes Kissimmee and Tohopekaliga, afford a steamboat route between the town Kissimmee and Fort Bassenger.

Numerous other routes are followed by steamboats on the inland waterways of the Atlantic coast and are mostly characterized by regularity of service and by lack of hindrances to navigation, except on the northern waterways in winter.

MISSISSIPPI VALLEY, INCLUDING GULF COAST.

The principal steamboat routes of the Mississippi Valley and Gulf coast may be grouped according to some central river port, as Cincinnati, St. Louis, Memphis, Vicksburg, New Orleans, or Mobile. From Cincinnati regular lines of boats extend up the Ohio River as

far as Pittsburgh and down the Ohio and Mississippi to Memphis; up the Ohio and Great Kanawha to Charleston, W. Va.; and an important line plies nightly between Cincinnati and Louisville. In addition to these, a number of other lines give regular service at Cincinnati. The longest route followed regularly from Cincinnati is the one to Memphis, 749 miles away. From Cincinnati to Pittsburgh the distance is 470 miles; from Cincinnati to Charleston, 263; and from Cincinnati to Louisville the distance is 128 miles.

From St. Louis regular lines reach to St. Paul on the upper Mississippi and to Memphis on the lower; and extend also up the Missouri River to Kansas City, up the Illinois to Peoria, and on the Mississippi, Ohio, and Tennessee Rivers to Waterloo, Ala.

Steamboat lines from Memphis reach points as far down the Mississippi River as Vicksburg, the up-river boats, as has been said, running from Memphis as far as St. Louis on the one hand and Cincinnati on the other.

Another important steamboat center in the Mississippi Valley is New Orleans. From this port steamboats serve landings as far up the Mississippi River as Vicksburg, and at least one line of boats follows the Mississippi, Red, and Black Rivers up to Harrisonburg, La.

Various other routes are followed through the network of rivers, bayous, and canals in the traffic between New Orleans and numerous towns and landings in southern Louisiana as far west as Bayou Teche and as far north as Red River. The variation in distances traveled by steamboats between New Orleans and St. Martinville on Bayou Teche illustrates the intricacies of the bayou routes. The trip by way of the Mississippi River and the Plaquemine waterways is 257 miles. By way of Harveys Canal, Bayou Barataria, Lake Salvador, Harang Canal, Bayou Lafourche, a private canal, Bayou Terrebonne, Barrows Canal, Bayous Black, Chene, and Boeuf, Berwick Bay, and Bayou Teche, the steamboat route is 192 miles; and by still another but shorter series of waterways the distance is reduced to 178 miles between New Orleans and St. Martinville.

Another group of steamboat routes from New Orleans consists of those reaching points on Lake Ponchartrain.

Of the many products carried on these various groups of steamboat routes from New Orleans, cotton may be taken as the typical commodity carried on the routes extending northward, sugar on the routes of the bayou region, and fruit and vegetables on Lake Ponchartrain.

Of the Gulf slope, as distinct from the Mississippi Valley proper, Mobile is one of the principal river ports. From this city steamboat lines extend up the Mobile, Alabama, and Tombigbee Rivers to Montgomery, Selma, Demopolis, and minor landings. Cotton is one of the most important agricultural products carried on these waterways.

The old route from New Orleans to St. Louis on the one hand, or to Cincinnati on the other, is no longer followed by any one line of boats. From the pioneer days of steamboating until a few decades after the Civil War, New Orleans was reached by lines terminating at St. Louis and Cincinnati, but with the development of railroads and improvement of their service steamboat traffic gradually changed in its nature, so that the bulk of the freight movement became local, and long-distance shipments grew less and less important. With the passing of the Anchor Line in the early nineties, St. Louis ceased to be connected with the city of New Orleans by any direct line of packets, and about 10 years later through freight service also ceased when the line of barges and towboats operated by the Mississippi Valley Transportation Co. went out of business. The through traffic consisting of large tows of coal barges, taken from Pittsburgh down to New Orleans, is not to be classed with regular steamboat-line service, which is conducted according to fixed schedules of arrivals and departures.

PACIFIC COAST.

One important system of waterways on the Pacific coast consists of the rivers emptying into San Francisco Bay; the Sacramento from the north and the San Joaquin from the south. The delta near the junction of these two rivers affords a number of channels which are used by various boats and which afford transportation to a rich truck region not conveniently reached by rail. The principal centers of steamboat traffic here are San Francisco, Sacramento, and Stockton. Each of these cities is connected with the other two and with numerous landings by regular lines of boats. Here, as well as on the Atlantic coast, sail vessels (especially on the lower river) and gasoline launches share in transportation. Here, also, barges are used to increase the capacity of steamboats in handling the large amount of business on this inland water system. One characteristic of this traffic is the large quantity of potatoes, beans, asparagus, and other vegetables. Their tonnage is great enough to give a distinctive character to the commerce, although grain, hay, and other products are carried in considerable quantities. Another important item in the river trade is milk shipped to the cities of San Francisco, Sacramento, and Stockton.

A second important system of waterways consists of the Columbia River and its tributaries. On the lower section of the river steamboats from Portland, on the Willamette a few miles from the Columbia, run down the Columbia to Astoria and others run up the river as far as Celilo Falls. Other routes extend from just above the falls to various points on the upper Columbia and Snake Rivers. On the upper Columbia one line connects Wenatchee with Bridgeport.

LOCAL TRAFFIC.

The steamboat routes thus described illustrate the fact that river traffic is generally local. A few hundred miles is usually the maximum length of the route of any one line of steamboats. In fact, it may be said that a run of 400 miles or more is exceptional. Of the 92 routes specified in Table 4, only 16 are more than 250 miles in length, which is slightly more than the average length of haul for all freight carried on railroads in the United States. In other words, steamboat traffic is distinctly short-haul traffic. The business of the boats in general is to concentrate at important centers freight picked up at local landings and to distribute to those landings commodities shipped from the trade centers. Again, it is to be noted that this applies to the river trade in general and not to such movements as the barge traffic in coal from the Pittsburgh region.

CHARACTERISTICS OF STEAMBOAT FREIGHT RATES.

There is a great variety of freight tariffs for steamboat river trade. The unit of quantity in some cases is 100 pounds or the short ton, and in others the package. Some boats quote rates for carlots lower than for less than carlots, as is done in railroad freight tariffs. Specific conditions give rise in many cases to specific rates. A certain commodity may be carried in one direction for a lower rate than in another, if the trade in the favored direction is large enough to justify special concessions in order to obtain it. Distance frequently has little or no influence upon the rate charged by boat. Sometimes over an entire route the same rate will be charged between any two landings regardless of distance.

The minimum charge for a single shipment by water is by no means uniform throughout the country. In Louisiana the minimum charge for a single package is 10 cents and for a single shipment is 25 cents, but if the boat has to make a special landing for a single shipment the charge is at least 50 cents. The steamboat tariff authorized by the State of Alabama specifies a minimum charge of 15 cents on a single shipment.

An example of the variety of packages taken as bases for steamboat freight rates is afforded in the Potomac River trade, between landings down the river and Washington. Rates on apples are as follows: 30 cents per sugar barrel, 25 cents per flour barrel, 15 cents per half-barrel basket, 12 cents per bushel basket, 10 cents per box, 15 cents per bag, and 13 cents per small carrier; also 15 cents per two-basket carrier, and 8 cents per basket of five-eighths of a bushel.

ILLUSTRATIONS AFFORDED BY THE NORFOLK TRADE.

A large amount of freight is carried between Baltimore and Norfolk by bay steamers. This traffic, except where commodity rates apply, is subject to the Southern Classification, which ranges from 10 cents per 100 pounds for class 6 to 26 cents for class 1, and from 10 cents

per 100 pounds for class A to 16 cents for class B and class H. An important group of commodities carried over this route consists of fresh fruits and vegetables. Some of the freight rates applying to these products are of considerable importance to the fruit and truck industry of the Norfolk region. The following rates applied in 1912 to shipments from Norfolk to Baltimore: Berries were charged from 18 cents per crate of 24 quarts to 42 cents per 60-quart crate; fresh fruits, 7 cents per bushel box, 11 cents per half-barrel box or carrier, 20 cents per standard vegetable barrel, and 25 cents per sugar barrel; cabbage, cucumbers, and spinach, 15 cents per flour barrel and 20 cents per sugar barrel; lettuce and potatoes, 20 cents per flour barrel and 23 cents per sugar barrel; tomatoes, 11 cents per half-barrel carrier; and watermelons, 2½ cents each. The charge on cotton in square bales was 40 cents per bale if compressed, and 50 cents if not compressed. Cotton in cylindrical bales was charged at the rate of 10 cents per 100 pounds.

FREIGHT TARIFF ZONES.

An example of the application of what may be termed "zone rates" is afforded by the tariffs established by the Railroad Commission of Alabama for the Alabama and Tombigbee Rivers. Freight tariff No. 3 of this series applies to shipments between Mobile and three principal cities up the river—Demopolis, Montgomery, and Selma. This tariff is based chiefly upon the Southern Classification. Cotton and cement are given special rates, but other articles are charged according to their respective "classification." The six numbered classes are charged from 30 cents per 100 pounds for articles in class 1 to 10 cents per 100 pounds for those in class 6, and the lettered classes 9 cents per 100 pounds for articles in class A to 19 cents per 100 pounds for those in class H. Articles coming under class F are charged 20 cents per barrel. The rates just quoted apply to shipments between Mobile and any of the three cities mentioned. Freight tariff No. 2 applies to shipments between Mobile, Demopolis, and points located between those cities. This schedule of rates is chiefly a "commodity" tariff, each article being given a special rate. For landings in general on the Alabama and Tombigbee Rivers and their tributaries tariff No. 1, also a "commodity" tariff, applies.

Another instance of a zone system of freight rates is that afforded on the route between Evansville, Ind., and Bowling Green, Ky., including parts of the Ohio, Green, and Big Barren Rivers. There is a special tariff between Evansville and Bowling Green. Other landings are divided into four groups, according to their distance from Evansville, No. 1 being the nearest to that place. The freight rate from all landings on the Tennessee River between Florence, Ala., and its mouth, to and from St. Louis, is the same for a given commodity. It costs as much to ship from St. Louis to any one landing in this territory as to another.

BLANKET RATES.

An example of a "blanket" or "postage-stamp" rate—that is, the same charge for a given commodity between any two landings—is afforded by the traffic on the Apalachicola River and its tributaries. Also the tariff for river boats, issued under the authority of the Railroad Commission of Louisiana, No. 8467-S, applies to traffic between any two landings from New Orleans up to Devalls Landing. A large number of commodities are separately rated. For those not included in the commodity rates the Western Classification as used by railroads applies. The numbered classes, which apply to less-than-carload shipments, are charged from 15 cents for class 5 to 30 cents per 100 pounds for class 1; and the lettered classes, which apply to carload shipments, are charged from 8 cents for class E to 15 cents per 100 pounds for class A.

UNIFORM BASIS OF COMPARISON.

Detailed information as to freight rates and distances are shown in Table 2. The original quotations of freight rates when expressed in other units were reduced to cents per 100 pounds in order to facilitate comparison. The column in Table 2 giving the rates per ton per mile has been computed in order to compare short-distance with long-distance shipments on a uniform basis. While in practice distance frequently has but little to do with cost over a single route, nevertheless it is logical to use length of haul as a factor in comparing the cost of various services of transportation. While it may not cost the shipper more to send his product 50 miles than to send it 10, the cost to the carrier is greater for the 50 miles and consequently, from the carrier's point of view, the service rendered is greater. Therefore, in comparing one cost with another, and taking into account service rendered, the ton-mile rate may be used to advantage. However, care should be taken in comparing the ton-mile rate between two points over one route with the corresponding rate between the same points over a longer or shorter route. Here the actual service rendered to the owner of the freight is not necessarily greater or less over the longer route than the short one.

GROUPS OF WATERWAYS.

Water routes are divided in Table 2 into three classes or groups: The Atlantic slope, the Mississippi Valley, including the Gulf slope, and the Pacific slope. Under each group the quotations and routes are arranged in order of distance, beginning with the shortest. Since the data in Table 2 are not comprehensive enough for satisfactory averages to be made from them, no such averages are shown here. The data are, however, complete enough to illustrate costs of transportation over long, medium, and short steamboat routes.

RAIL AND WATER RATE COMPARED.

Some important routes and commodities are selected for comparing rail and water rates in Table 3. Between Hartford, Conn., and New York City the rates on apples, eggs, hay, and potatoes, as well as other commodities, are the same by rail as by water; that is, the rates paid by the shippers. Reduced to cents per short ton per mile, the rate by water appears much less, since the distance by water is 52 miles greater than by rail.

Between Cincinnati and Pittsburgh the actual as well as the ton-mile rates are much lower by water than by rail on the commodities represented in Table 3. These are not exceptions; lower rates by water than by rail are general over this route. However, between Charleston, W. Va., and Cincinnati the steamboat charge per package, when reduced to an equivalent cents per 100 pounds, indicates higher rates for apples and eggs by boat than by rail. The rate on hay, however, by boat over this route is $12\frac{1}{2}$ cents per 100 pounds for either small or large lots, while by rail 22 cents is charged for less than carloads and 12 cents per 100 pounds for carloads. For potatoes the boat charges per package is equivalent to 13 cents per 100 pounds, while the railroad charges 15 cents for less-than-carload lots and 12 cents per 100 pounds for car lots. The steamboat rate applies to any quantity. Between Cincinnati and Memphis and between Memphis and St. Louis the boats quote higher rates than the railroad for eggs, when the boat rates are reduced from cents per package to cents per 100 pounds. In practically all other rates shown in Table 3 between Memphis and the two cities just named the charge by water is less than by rail.

DISTANCE AND TIME OF TRANSIT.

It is convenient to express the average rate of transit in miles per hour, but it should be distinctly understood that this rate should be applied to a number of hours—say, 12 or 24—in order to make a satisfactory application for practical purposes. The rate itself has been computed by dividing the total number of hours in transit into the total miles run, and includes all stops at landings. Thus, if an average rate is given as 4 miles per hour, it means that a day's run of a vessel, say, of 12 hours, will cover 48 miles; or, if the rate is only 2 miles per hour, the day's run will cover possibly 24 miles; or, with 24 hours for the unit, a local boat making various landings and averaging 3 miles per hour will cover a distance of 72 miles in the 24 hours. It will be noted that the average rate of transit is subject to wide variations, some as low as 2 miles per hour and some reaching 15. This is governed partly by the speed of the boat while under way, but largely by the number of landings made in transit.

NUMBER OF LANDINGS.

To illustrate the influence of the number of landings on the average rate of speed, Table 5 has been compiled. Between Cincinnati and Memphis 346 landings are reported over a distance of 749 miles, making an average of about 2 miles between landings. Between St. Louis and Memphis 318 landings are reported for 415 miles. Of the six routes in Table 5 illustrating Mississippi Valley conditions, the average distance between landings ranges from 1.30 miles to 3.31 miles.

From Baltimore, Md., to Fredericksburg, Va., a distance of 285 miles, 34 landings are reported. These are all on the Rappahannock River, extending along a distance of 106 miles, there being an average of 3.12 miles between landings. From Hartford, Conn., to New York City there are 12 intermediate landings for a certain line of steamers, which 12 landings are all on the Connecticut River, and their average distance apart is 4.33 miles. One of the fastest rates of transit on inland water routes is between Baltimore and Norfolk, a distance of 184 miles with but one intermediate stop.

SUMMARY OF RATES OF TRANSIT.

In Table 4 there are 102 routes for which rates of transit are given. Of these, 15 show an average rate of less than 4 miles an hour, 22 average 4 miles to less than 6, 19 routes have an average of 6 to less than 8, and 21 routes an average of 8 and less than 10 miles per hour, making 62 out of 102 showing from 4 to less than 10 miles per hour; 25 rates of speed were 10 miles and over, 15 of them from 10 to less than 12 miles, and 10 rates were 12 miles and over. Of the 50 instances reported for the Mississippi Valley, including the Gulf slope, 29 were rates of 4 to less than 8 miles per hour, 12 rates were less than 4 miles, and 9 were 8 miles and over per hour. On the Atlantic slope 32 out of 43 rates were at least 8 miles per hour and 11 rates were less than 8 miles per hour. The nine reports from the Pacific slope showed five instances of 8 to less than 12 miles per hour and four instances of 4 to less than 8 miles per hour.

FREIGHT RATES AND FARM PRICES.

A practical use of the data compiled in this bulletin is to compare freight rates with prices. This may be done here, for the sake of illustration and to indicate the method. For instance, the rate on apples over a certain 25-mile route in Maine was 15 cents per barrel in September and October, 1912. The average farm price for all apples in the State those months was \$1.725 per barrel, making the freight rate 8.7 per cent, over this specific route, of the farm price in the whole State for all kinds. For a 24-mile route in New York, the freight rate happening to be 15 cents per barrel also,

made 10 per cent of the farm price for the State. In this case the average farm price of apples for New York State was \$1.50 per barrel. While the prices mentioned do not necessarily apply to the actual commodities carried subject to these rates, both prices and rates are representative enough to give a fair measure of relationship. These percentages are as low as 6.67 for a 33-mile route in New York and as high as 34.25 per cent over a 239-mile route in the Pacific northwest. In cotton traffic, quotations of the freight rates by boat in a number of instances range from about 0.9 of 1 per cent of the farm price to slightly more than 3 per cent, most of the instances noted showing less than 2 per cent. Eggs are charged from one-half of 1 to as high as 10 per cent of their farm value for water transportation. Hay, owing to its large bulk as compared with price, is frequently charged from 10 to 40 per cent of its farm price for freight. Potatoes compare with apples in the percentage of the freight rate, as based upon the average farm price. For wheat, from 3 to 15 per cent of its farm value is equivalent to the freight rate. The average farm price meant here is the price received by the farmer for delivery to shipping point, and does not include freight charge.

TABLE 1.—Receipts of various farm products by water compared with total receipts, at selected cities.

[Sources: Baltimore Daily Produce Report, Cincinnati Chamber of Commerce, St. Louis Merchants' Exchange, Memphis Cotton Exchange, and New Orleans Cotton Exchange.]

City, product, and year.	Receipts.			City, product, and year.	Receipts.		
	Total quantity.	By river.			Total quantity.	By river.	
		Quantity.	Per cent of total.			Quantity.	Per cent of total.
<i>Baltimore, Md.¹</i>				<i>Cincinnati, Ohio—Continued.</i>			
Corn (bushels):				Corn (bushels):			
1908.....	13,665,794	1,100,000	8.0	1908.....	7,763,457	5,976	0.1
1909.....	10,213,817	1,500,000	14.7	1909.....	7,145,408	5,682	.1
1910.....	10,428,779	400,000	3.8	1910.....	8,631,574	3,590	.04
1911.....	14,482,742	700,000	4.8	1911.....	9,367,710	4,678	.04
1912.....	13,197,593	400,000	3.0	1912.....	9,806,063	2,786	.02
Wheat (bushels):				Eggs (cases):			
1908.....	9,865,044	1,700,000	17.2	1908.....	441,072	27,456	6.2
1909.....	5,821,809	600,000	10.3	1909.....	519,652	26,340	5.1
1910.....	6,723,673	2,000,000	29.7	1910.....	511,519	32,840	6.4
1911.....	11,088,586	2,000,000	18.0	1911.....	605,131	33,367	5.5
1912.....	12,488,385	1,300,000	10.4	1912.....	668,942	31,072	4.6
<i>Cincinnati, Ohio.</i>				Hay (tons):			
Apples (barrels):				1908.....	156,151	1,692	1.1
1908.....	373,163	1,254	.3	1909.....	167,263	3,093	1.8
1909.....	240,587	7,174	3.0	1910.....	189,262	3,275	1.7
1910.....	521,814	31,036	5.9	1911.....	155,195	3,139	2.0
1911.....	293,204	7,057	2.4	1912.....	151,238	1,454	1.0
1912.....	378,524	45,849	12.1	Hogs (number):			
Cattle (number):				1908.....	1,278,522	48,142	3.8
1908.....	274,520	3,751	1.4	1909.....	951,522	41,034	4.3
1909.....	293,331	4,474	1.5	1910.....	838,850	35,227	4.2
1910.....	312,962	3,630	1.2	1911.....	1,135,121	45,585	4.0
1911.....	312,143	3,020	1.0	1912.....	1,224,949	49,367	4.0
1912.....	342,249	6,343	1.9				

¹ Receipts at Baltimore "by river" refer to receipts from landings in Chesapeake Bay and its tributaries.

TABLE 1.—Receipts of various farm products by water compared with total receipts, at selected cities—Continued.

City, product, and year.	Receipts.			City, product, and year.	Receipts.		
	Total quantity.	By river.			Total quantity.	By river.	
		Quantity.	Per cent of total.			Quantity.	Per cent of total.
<i>Cincinnati, Ohio—Continued.</i>				<i>St. Louis, Mo.</i>			
Potatoes (bushels):				Apples (barrels):			
1903.....	2,472,724	36,717	1.5	1903.....	306,192	37,530	12.3
1909.....	2,012,009	21,597	1.1	1909.....	317,664	62,014	19.5
1910.....	2,394,621	60,839	2.5	1910.....	248,615	60	.02
1911.....	2,364,427	31,832	1.3	1911.....	411,808	222,563	54.0
1912.....	2,428,562	31,407	1.3	1912.....	433,891	213,531	49.2
Sheep (number):				Apples (boxes):			
1903.....	485,278	13,033	2.7	1903.....	97,295	35	.03
1909.....	491,206	14,713	3.0	1909.....	70,350	182	.3
1910.....	503,715	18,632	3.7	1910.....	135,730	45	.03
1911.....	546,989	10,898	2.0	1911.....	104,995	2,062	2.0
1912.....	500,386	12,236	2.4	1912.....	337,910	960	.3
Tobacco (cases and bales):				Cattle (number):			
1903.....	54,717	46	.1	1903.....	1,293,564	11,671	.9
1909.....	53,918	143	.3	1909.....	1,418,005	9,320	.7
1910.....	43,810	67	.1	1910.....	1,356,232	6,552	.5
1911.....	43,902	147	.3	1911.....	1,206,423	8,073	.7
1912.....	73,097	38	.1	1912.....	1,298,295	8,422	.6
Tobacco (hogsheads):				Cotton, for local use (bales):			
1903.....	63,798	14,064	20.4	1903.....	128,452	7,562	5.9
1909.....	64,013	6,742	10.5	1909.....	108,257	4,277	4.0
1910.....	70,370	9,832	14.0	1910.....	78,786	3,100	3.9
1911.....	82,122	15,129	18.4	1911.....	115,552	7,469	6.5
1912.....	75,510	15,059	19.9	1912.....	101,389	4,140	4.1
Wheat (bushels):				Eggs, for local use (packages):			
1903.....	4,052,264	41,288	1.0	1903.....	605,197	28,869	4.8
1909.....	4,178,771	34,603	.8	1909.....	443,591	23,929	5.4
1910.....	3,776,828	19,714	.5	1910.....	522,365	21,961	4.2
1911.....	3,946,631	26,003	.7	1911.....	807,509	22,485	2.8
1912.....	3,235,605	8,440	.3	1912.....	615,741	21,739	3.5
Wool (bales):				Hogs (number):			
1903.....	135,702	490	.4	1903.....	3,199,922	103,399	3.4
1909.....	78,994	336	.4	1909.....	3,076,065	83,389	2.7
1910.....	54,421	558	1.0	1910.....	2,548,480	60,343	2.4
1911.....	52,713	444	.8	1911.....	3,634,851	98,044	2.7
1912.....	127,783	1,083	.8	1912.....	3,023,739	72,778	2.4
<i>Memphis, Tenn.</i>				Sheep (number):			
Cotton (bales):				1903.....	724,781	16,030	2.2
1903.....	750,442	102,195	13.6	1909.....	835,973	16,446	2.0
1909.....	984,370	101,648	10.3	1910.....	776,665	14,321	1.8
1910.....	785,485	91,324	11.6	1911.....	1,024,402	15,037	1.5
1911.....	920,887	98,376	10.7	1912.....	1,052,208	14,315	1.4
1912.....	969,670	107,827	11.1	Wheat (bushels):			
<i>New Orleans, La. (for years ending Aug. 31).</i>				1903.....	19,047,240	¹ 350,178	1.8
Cotton (bales):				1909.....	21,372,726	¹ 373,040	1.7
1903.....	2,015,071	146,516	7.3	1910.....	19,642,312	¹ 391,512	2.0
1909.....	2,107,956	77,896	3.7	1911.....	17,025,604	¹ 393,018	2.3
1910.....	1,342,112	50,059	3.7	1912.....	30,516,432	¹ 194,148	.6
1911.....	1,629,303	60,894	3.7	Wool (pounds):			
1912.....	1,709,023	87,803	5.1	1903.....	23,123,340	252,350	1.1
				1909.....	22,649,110	35,600	.2
				1910.....	21,044,440	211,320	1.0
				1911.....	26,773,770	390,840	1.5
				1912.....	23,390,150	317,510	1.4

¹ Reported in number of sacks; reduced to bushels by assuming 1 sack to average 2 bushels.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912.*

[Sources: Freight rates as reported by representatives of steamboats or steamboat lines; distances chiefly as furnished by Chief of Engineers, United States Army.]

APPLES.

Route.	Waterway.	Dis- tance.	Freight rates.					
			On small lots, or any quantity.			On large lots, where specially quoted.		
			As quoted to shippers.	Per 100 pounds.	Per short ton per mile.	As quoted to shippers.	Per 100 pounds.	Per short ton per mile.
<i>Atlantic slope.</i>			<i>Miles.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Between—	Hudson River.	12	10 per bbl.	16.29	1 10.48			
Newburgh and Wappinger Falls, N. Y.	do.	16	do.	16.29	17.86			
Newburgh and Poughkeepsie, N. Y.	Connecticut River.	20	9 per 100 lbs.	9.00	9.00	6 per 100 lbs.	6.00	6.00
Hartford and Middletown, Conn.	Lake Champlain.	22	10 per 100 lbs.	10.00	9.09	5 per 100 lbs.	5.00	4.55
Burlington, Vt., and Plattsburg, N. Y.	Kennebec River.	24	15 per bbl.	19.43	17.86			
Gardiner and Bath, Me.	Hudson River.	24	15 per bbl.	19.43	17.86			
Newburgh and Haverstraw, N. Y.	do.	33	10 per bbl.	16.29	13.81	10 per bbl.	16.29	15.24
Albany and Catskill, N. Y.	Lake Champlain.	40	10 per 100 lbs.	10.00	5.00	5 per 100 lbs.	5.00	2.50
Burlington and St. Albans Bay, Vt.	Connecticut River.	41	10 per 100 lbs.	10.00	4.88	7 per 100 lbs.	7.00	3.41
Hartford and West Haddam, Conn.	do.	49	12 per 100 lbs.	12.00	4.90	8 per 100 lbs.	8.00	3.27
Hartford and Lyme, Conn.	Hudson River.	91	20 per bbl.	112.58	12.77	7 per 100 lbs.	7.00	1.54
Newburgh and Troy, N. Y.	do.	98	18 per bbl.	111.32	12.31			
New York and Saugerties, N. Y.	do.	162	16 per 100 lbs.	16.00	1.98	11 per 100 lbs.	11.00	1.36
Hartford, Conn., and New York, N. Y.	Connecticut River and Long Island Sound.							
Baltimore, Md., and Norfolk, Va.	Chesapeake Bay.	184	20 per vegetable bbl. ²	112.58	1.37			
<i>Mississippi Valley, including Gulf slope.</i>								
Between—	Ohio River.	25	15 per 100 lbs.	15.00	12.00			
Shawneetown and Cave in Rock, Ill.	Great Kanawha River.	28	10 per bbl.	16.29	14.49			
Charleston and Montgomery, W. Va.	Ohio River.	45	15 per bbl.	19.43	14.19	10 per bbl.	16.29	12.80
Cairo, Ill., and Paducah, Ky.	Mississippi River.	54	12 per bbl.	17.55	12.80			
Alton and Hamburg, Ill.	Ohio River.	76	15 per bbl.	19.43	12.48			
Shawneetown and Rosiclare, Ill.	Ohio River.	90	15 per bbl.	19.43	12.10			
St. Louis, Mo., and Hamburg, Ill.	Mississippi River.	107	10 per 100 lbs.	10.00	1.87			
St. Louis and Louisiana, Mo.	do.	128	15 per bbl.	19.43	11.47			
Cincinnati, Ohio, and Louisville, Ky.	Ohio River.	137	20 per bbl.	112.58	11.84			
Evansville, Ind., and Paducah, Ky.	do.							

² Northbound.

¹ Assuming average gross weight of 1 barrel of apples to be 159 pounds.

¹ Assuming average gross weight of 1 barrel of apples to be 159 pounds.² Northbound.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912—Continued.*

APPLES—Continued.

Route.	Waterway.	Dis- tance.	Freight rates.				
			On small lots, or any quantity.			On large lots, where specially quoted.	
			As quoted to shippers.	Per 100 pounds.	Per short ton per mile.	As quoted to shippers.	Per 100 pounds.	Per short ton per mile.
<i>Mississippi Valley, including Gulf slope— Continued.</i>		<i>Miles.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Between—							
Evansville, Ind., and Louisville, Ky.	Ohio River	185	7 per 100 lbs.	7.00	.76		
Evansville, Ind., and Bowling Green, Ky.	Ohio, Green, and Big Barren Rivers.	190	25 per bbl.	115.72	1.65		
Cincinnati, Ohio, and Parkersburg, W. Va.	Ohio River	200	20 per bbl.	112.58	1.26		
St. Louis, Mo., and Peoria, Ill.	Mississippi and Illinois Rivers.	200	25 per bbl.	115.72	1.57	20 per bbl.	112.58
Cincinnati, Ohio, and Charleston, W. Va.	Ohio and Great Kanawha Rivers.	263	do	115.72	1.20		1.26
Pittsburgh, Pa., and Charleston, W. Va.	do	325	30 per bbl.	118.87	1.16	20 per bbl.	112.58
St. Paul, Minn., and Davenport, Iowa.	Mississippi River	378	18 per 100 lbs.	18.00	.95		1.77
St. Louis and Kansas City, Mo.	Mississippi and Missouri Rivers.	407	28 per 100 lbs.	28.00	1.38	22 per 100 lbs.	22.00
St. Louis, Mo., and Memphis, Tenn.	Mississippi River	415	30 per bbl.	118.87	1.91	20 per bbl.	12.58
Cincinnati, Ohio, and Pittsburgh, Pa.	Ohio River	470	20 per bbl.	112.58	1.54	15 per bbl.	19.43
<i>Pacific slope.</i>							
Between—							
Kennewick and White Bluffs, Wash.	Columbia River.	42	20 per 100 lbs.	20.00	9.52		
Wenatchee and Bridgeport, Wash.	do	79	15 per 100 lbs.	15.00	3.80		
Kennewick, Wash., and Portland, Oreg.	Columbia and Willamette Rivers.	239	42 per 100 lbs.	42.00	3.51	28 per 100 lbs.	28.00
							2.34

COTTON.

<i>Atlantic slope.</i>							
Between—							
Georgetown and Conway, S. C.	Waccamaw River.	46	10 per 100 lbs.	10.00	4.35		
Savannah, Ga., and Beaufort, S. C.	Savannah and Beaufort Rivers.	60	do	10.00	3.33		
Georgetown and Cains Landing, S. C.	Peedee River	85	75 per bale	215.00	2.49		
Baltimore, Md., and Norfolk, Va.	Chesapeake Bay	184	50 per bale	210.00	2.10		
Baltimore, Md., and West Point, Va.	Chesapeake Bay and York River.	195	do	210.00	2.10		
Savannah and Augusta, Ga.	Savannah River	202	80 per bale	216.00	2.15		
Brunswick and Macon, Ga.	Altamaha and Ocmulgee Rivers.	370	20 per 100 lbs.	20.00	1.08	19 per 100 lbs.	19.00
							1.93

Mississippi Valley, including Gulf slope.

Between—						
Shiloh, Tenn., and Riverton, Ala.....	34	20 per 100 lbs. ³	20.00	11.76		
Memphis, Tenn., and White Hall, Ark.....	65	50 per bale.....	10.00	23.08		
Albany and Bainbridge, Ga.....	69	10 per 100 lbs.....	10.00	2.90		
Vicksburg and Natchez, Miss.....	100	75 per bale.....	15.00	2.80		
Memphis, Tenn., and Tipton Point, Miss.....	105	do.....	15.00	2.86		
Apalachicola, Fla., and Bainbridge, Ga.....	173	10 per 100 lbs.....	10.00	1.16		
Apalachicola and Flint Rivers.....	209	100 per bale.....	20.00	1.91		
Memphis, Tenn., and Arkansas City, Ark.....						
Shiloh, Tenn., and Paducah, Ky.....	227	20 per 100 lbs.....	20.00	1.76		
Mobile and Demopolis, Ala.....	230	75 per bale.....	15.00	1.30		
Mobile and Alabama Rivers.....	308	do.....	15.00	2.97		
New Orleans and Harrisonburg, La.....	340	125 per bale.....	25.00	2.17		
Apalachicola, Fla., and Columbus, Ga.....	360	50 per bale.....	10.00	2.56		
Vicksburg, Miss., and Memphis, Tenn.....	370	90 per bale.....	18.00	2.97		
Memphis, Tenn., and St. Louis, Mo.....	415	75 per bale.....	15.00	2.72		
New Orleans, La., and Carroll, Ark.....	446	125 per bale.....	25.00	2.12		
Shiloh, Tenn., and St. Louis, Mo.....	477	35 per 100 lbs.....	35.00	1.47		
Tennessee, Ohio, and Mississippi Rivers.....						
Mississippi and Ohio Rivers.....	749	100 per bale.....	20.00	2.53		

EGGS.

Between—						
<i>Atlantic slope.</i>						
Newburgh and Wappingers Falls, N. Y.....	12	8 per case.....	45.09	425.15		
Philadelphia Pa., and Billingsport, N. J.....	12	10 per case.....	48.87	431.45		
Albany and New Baltimore, N. Y.....	15	do.....	48.87	25.16	8 per case.....	4 20.12
Newburgh and Poughkeepsie, N. Y.....	16	do.....	48.87	23.59		
Philadelphia, Pa., and Bridgeport, N. J.....	18	do.....	48.87	40.97		
Hartford and Middletown, Conn.....	20	11 per 100 lbs.....	11.00	11.00		
Burlington, Vt., and Plattsburg, N. Y.....	22	8 per 100 lbs.....	8.00	7.27		
Gardiner and Bath, Me.....	24	25 per case.....	47.17	439.31		
Newburgh and Haverstraw, N. Y.....	24	10 per case.....	48.87	45.72	8 per case.....	4 12.58
Jacksonville and Green Cove Springs, Fla.....	30	do.....	48.87	42.58		
Philadelphia, Pa., and Wilmington, Del.....	31	10 per 100 lbs.....	10.00	6.45		
Albany and Castkill, N. Y.....	33	10 per case.....	48.87	41.44		
Philadelphia, Pa., and Trenton, N. J.....	36	9 per case.....	46.98	49.43	10 per 100 lbs.....	10.00 5.56
Burlington and St. Albans Bay, Vt.....	40	12 per 100 lbs.....	12.00	6.00		
Lake George and Baldwin, N. Y.....	40	18 per 100 lbs.....	18.00	9.00		
Hartford and East Haddam, Conn.....	41	12 per 100 lbs.....	12.00	5.85		
Philadelphia, Pa., and Suem, N. J.....	45	10 per case.....	48.87	48.39		
Delaware River.....	45	16 per 100 lbs.....	16.00	7.11		
do.....						
Wacoctaw River.....	46	41 per 100 lbs.....	41.00	17.83		

¹ Assuming average gross weight of 1 barrel of apples to be 159 pounds.² Assuming average gross weight of 1 bale of cotton to be 500 pounds.³ Uncompressed only.⁴ Assuming average gross weight of 1 case of eggs (30 dozen) to be 53 pounds.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912*—Continued.

EGGS—Continued.

Route.	Waterway.	Dis- tance.	Freight rates.				
			On small lots, or any quantity.		On large lots, where specially quoted.		
			As quoted to shippers.	Per 100 pounds, ton per mile.	As quoted to shippers.	Per 100 pounds, ton per mile.	Per short ton per mile.
		Miles.	Cents.	Cents.	Cents.	Cents.	Cents.
<i>Atlantic slope</i> —Continued.							
Between—							
Hartford and Lyme, Conn.	Connecticut River.	49	14 per 100 lbs.	5.71			
Savannah, Ga., and Beaufort, S. C.	Savannah and Beaufort Rivers.	60	15 per 100 lbs.	5.00			
Georgetown and Chins Landing, S. C.	Peedee River.	86	25 per case.	147.17			
Philadelphia, Pa., and Frederica, Del.	Delaware River and Murder Kill Creek.	90	15 per case.	128.30			
Newburgh and Troy, N. Y.	Hudson River.	91	10 per case.	138.87			
New York and Saugerties, N. Y.	do.	98	15 per case.	128.30			
Norfolk and Richmond, Va.	Elizabeth and James Rivers.	116	22 per 100 lbs.	22.00			
Philadelphia, Pa., and Baltimore, Md.	Delaware River, canal, and Chesapeake Bay.	120	19 per 100 lbs.	19.00			
Baltimore and Salisbury, Md.	Chesapeake Bay and Wicomico River.	142	25 per case.	147.17			
Baltimore and Bristol, Md.	Chesapeake Bay and Patuxent River.	150	30 per case.	156.60			
Baltimore, Md., and Seaford, Del.	Chesapeake Bay and Nanticoke River.	160	25 per case.	147.17			
Hartford, Conn., and New York, N. Y.	Connecticut River and Long Island Sound.	162	19 per 100 lbs.	19.00			
Baltimore, Md., and Norfolk, Va.	Chesapeake Bay.	184	22 per 100 lbs.	22.00			
Baltimore, Md., and West Point, Va.	Chesapeake Bay and York River.	195	22 per 100 lbs.	22.00			
Savannah and Augusta, Ga.	Savannah River.	202	30 per case.	156.60			
Baltimore, Md., and Tappahannock, Va.	Chesapeake Bay and Rappahannock River.	225	30 per case.	156.60			
Baltimore, Md., and Fredericksburg, Va.	do.	285	30 per case.	156.60			
Brunswick and Macon, Ga.	Altamaha and Ocmulgee Rivers.	370	40 per 100 lbs.	40.00			
<i>Mississippi Valley, including Gulf slope.</i>							
Between—							
Shawneetown and Cairo in Rock Ill.	Ohio River.	25	15 per 100 lbs.	15.00			
Charleston and Montgomery, W. Va.	Great Kanawha River.	28	10 per case.	118.87			
Cairo, Ill., and Paducah, Ky.	Ohio River.	45	15 per case.	128.30			
Lake Charles and Cameron, La.	(2 per dozen) ²	53	1112.21	142.72			
Charleston, W. Va., and Gallipolis, Ohio.	Calcasieu River and Lake.	62	(1 per dozen) ²	156.60			
Memphis, Tenn., and White Hall, Ark.	Great Kanawha and Ohio Rivers.	65	123.58	17.61			
	Mississippi River.		156.60	17.42			
					31 per 100 lbs.	31.00	1.68

Albany and Bainbridge, Ga.....	69	1 per dozen.....	156.60	116.41	.....
New Orleans and Donaldsonville, La.....	79	36 per case.....	153.00	14.33	.....
St. Louis, Mo., and Rip Rap, Ill.....	90	35 per case.....	128.30	16.29	.....
Viicksburg and Natchez, Miss.....	100	30 per case.....	156.00	11.32	.....
Chattanooga and Kingston, Tenn.....	104	25 per case.....	147.17	9.07	.....
Memphis, Tenn., and Friar Point, Miss.....	105	1 per dozen.....	156.00	10.78	.....
St. Louis and Louisiana, Mo.....	107	12½ per case.....	123.58	14.41	.....
Cincinnati, Ohio, and Louisville, Ky.....	128	15 per case.....	128.30	14.42	.....
Evansville, Ind., and Paducah, Ky.....	137	do.....	128.30	14.13	.....
Paducah, Ky., and Britts Landing, Tenn.....	138	¾ per dozen.....	142.45	16.15	128.30 14.10
Bismarck and V. illiston, N. Dak.....	150	15 per 100 lbs.....	15.00	2.00	.....
Chattanooga, Tenn., and Decatur, Ala.....	160	25 per case.....	147.17	15.90	.....
Apalachicola, Fla., and Bainbridge, Ga.....	173	1 per dozen.....	156.00	16.54	.....
New Orleans and Bayou Teche landings, La.....	175	do.....	156.60	16.47	.....
Evansville, Ind., and Louisville, Ky.....	185	22 per 100 lbs.....	22.00	2.38	.....
Evansville, Ind., and Bowling Green, Ky.....	190	40 per case.....	175.47	17.94	13.77
Cincinnati, Ohio, and Parkersburg, W. Va.....	200	15 per case.....	128.30	12.83	.....
St. Louis, Mo., and Peoria, Ill.....	200	25 per case.....	147.17	14.72	.....
Memphis, Tenn., and Arkansas City, Ark.....	209	do.....	147.17	14.51	.....
Mobile and Demopolis, Ala.....	230	35 per case.....	166.04	15.74	.....
Memphis, Tenn., and Cairo, Ill.....	254	1 per dozen.....	156.60	14.45	.....
Cincinnati, Ohio, and Charleston, W. Va.....	253	20 per case.....	137.74	12.87	.....
Mobile and Alabama Rivers.....	308	25 per 100 lbs.....	25.00	1.02	.....
Great Kanawha and Ohio Rivers.....	325	12½ per case.....	123.58	11.45	.....
Mississippi Rcd. and Black Rivers.....	340	1 per dozen.....	156.60	13.33	.....
Apalachicola and Chattahoochee Rivers.....	350	do.....	156.60	13.14	.....
Mississippi River.....	370	do.....	156.60	13.06	.....
do.....	378	18 per 100 lbs.....	18.00	95	.....
Mississippi and Missouri Rivers.....	407	36 per 100 lbs.....	36.00	1.77	28.00 1.38
Mississippi River.....	415	35 per case.....	166.04	13.18	.....
do.....	446	30 per case.....	156.60	12.54	.....
Mississippi, Ohio, and Tennessee Rivers.....	469	1 per dozen.....	156.60	12.41	.....
Ohio River.....	470	15 per case.....	128.30	11.20	.....
Ohio and Mississippi Rivers.....	743	40 per case.....	173.47	12.02	.....
<i>Pacific slope.</i>					
Between—					
Kennewick and White Bluffs, Wash.....	42	20 per 100 lbs.....	20.00	9.52	.....
Wenatchee and Bridgeport, Wash.....	79	50 per 100 lbs.....	50.00	12.66	.....
San Francisco and Walnut Grove, Cal.....	80	20 per 100 lbs.....	20.00	3.00	.....
San Francisco Bay and San Joaquin River.....	94	10 per 100 lbs.....	10.00	2.13	9 per 100 lbs..... 1.91
San Francisco Bay and Sacramento River.....	112	20 per 100 lbs.....	20.00	3.57	17 per 100 lbs..... 3.04

1 Assuming average gross weight of 1 case of eggs (30 dozen) to be 53 pounds.

2 These quotations are by different boats.

3 Average distance, as reported, via short routes.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912—Continued.*

HAY, BALED.

Route.	Waterway.	Dis- tance.	Freight rates.					
			On small lots, or any quantity.		On large lots, where specially quoted.			
			As quoted to shippers.	Per 100 pounds.	Per short ton per mile.	As quoted to shippers.	Per 100 pounds.	Per short ton per mile.
<i>Atlantic slope.</i>			<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Between— Newburgh and Wappingers Falls, N. Y. Philadelphia, Pa., and Billingsport, N. J.	Hudson River. Delaware River.	12 12	8 per 100 lbs. 10 per 100 lbs.	8.00 10.00	13.33 16.67			
Albany and New Baltimore, N. Y.	Hudson River.	15	15 per bale.	{ 17.50 215.00	110.00 250.00	10 per bale.	{ 15.00 210.00	16.67 213.33
Newburgh and Poughkeepsie, N. Y.	do.	16	8 per 100 lbs.	8.00	10.00			
Philadelphia, Pa., and Bridgeport, N. J.	Delaware River.	18	10 per 100 lbs.	10.00	11.11			
Philadelphia and Chester, Pa.	do.	18	8 per 100 lbs.	8.00	8.89			
Hartford and Middletown, Conn.	Connecticut River.	20	13 per 100 lbs.	13.00	13.00			
Burlington, Vt., and Plattsburg, N. Y.	Lake Champlain.	22	5 per 100 lbs.	5.00	4.55			
Gardiner and Bath, Me.	Kennebec River.	24	200 per ton.	10.00	8.33			
Newburgh and Haverstraw, N. Y.	Hudson River.	24	do.	10.00	8.33			
Philadelphia, Pa., and Wilmington, Del.	Delaware River.	31	12 per 100 lbs.	12.00	7.74			
Albany and Catskill, N. Y.	Hudson River.	33	15 per 100 lbs.	15.00	9.09			
Philadelphia, Pa., and Trenton, N. J.	Delaware River.	36	12 per 100 lbs.	12.00	6.67			
Burlington and St. Albans Bay, Vt.	Lake Champlain.	40	5 per 100 lbs.	5.00	2.50			
Lake George and Baldwin, N. Y.	Lake George.	40	15 per 100 lbs.	15.00	7.50			
Hartford and East Haddam, Conn.	Connecticut River.	41	14 per 100 lbs.	14.00	6.83			
Philadelphia, Pa., and Salem, N. J.	Delaware River.	45	10 per 100 lbs.	10.00	4.44			
Georgetown and Conway, S. C.	Waccamaw River.	46	7½ per 100 lbs.	7.50	3.26			
Hartford and Lyme, Conn.	Connecticut River.	49	16 per 100 lbs.	16.00	6.53			
Washington, D. C., and Mount Holly, Va.	Potomac River.	84	250 per ton.	12.50	2.98			
Georgetown and Cains Landing, S. C.	Pee Dee River.	86	10 per bale.	{ 15.00 210.00	11.16 22.33			
Philadelphia, Pa., and Frederica, Del.	Delaware River and Murder Kill Creek.	90	150 per ton.	7.50	1.67			
Newburgh and Troy, N. Y.	Hudson River.	91	19 per 100 lbs.	19.00	4.18			
New York and Saugerties, N. Y.	do.	98	250 per ton.	12.50	2.55			
Norfolk and Richmond, Va.	Elizabeth and James Rivers.	116	13 per 100 lbs.	13.00	2.24			
Baltimore and Salisbury, Md.	Chesapeake Bay and Wicomico River.	142	30 per 100 lbs.	30.00	4.23			
Baltimore and Bristol, Md.	Chesapeake Bay and Patuxent River.	150	do.	30.00	4.00			
Baltimore, Md., and Seaford, Del.	Chesapeake Bay and Nanticoke River.	160	do.	30.00	3.75			

		162	22 per 100 lbs.	22.00	2.72	11 per 100 lbs.	11.00	1.36
Hartford, Conn., and New York, N. Y.								
Connecticut River and Long Island Sound		195	13 per 100 lbs.	13.00	1.33	10 per 100 lbs.	10.00	1.03
Chesapeake Bay and York River.		232	15 per bale.	17.50	1.74			
Savannah and Augusta, Ga.		225	15 per 100 lbs.	15.00	1.46	12½ per 100 lbs.	12.50	1.11
Chesapeake Bay and Rappahannock River.		285	do.	15.00	1.33	do.	12.50	.88
do.					1.05			
Baltimore, Md., and Fredericksburg, Va.								
<i>Mississippi Valley, including Gulf slope.</i>								
Between—								
Charleston and Montgomery, W. Va.		28	150 per ton.	7.50	5.36	8 per 100 lbs.	8.00	3.96
Caro, Ill., and Paducah, Ky.		45	10 per 100 lbs.	10.00	4.44	150 per ton.	7.50	2.42
Great Kanawha and Ohio Rivers.		62	17½ per 100 lbs.	8.75	2.82			
Charleston, W. Va., and Gallipolis, Ohio		79	15 per 100 lbs.	15.00	3.80	7 per 100 lbs.	7.00	1.35
New Orleans and Donaldsonville, La		104	25 per 100 lbs.	25.00	4.81			
Chattanooga and Kingston, Tenn.		107	10 per 100 lbs.	10.00	1.87			
St. Louis and Louisiana, Mo.		128	20½ per ton.	10.00	1.56	150 per ton.	7.50	1.17
Cincinnati, Ohio, and Louisville, Ky.		137	10 per 100 lbs.	10.00	1.46	7½ per 100 lbs.	7.50	1.09
Evansville, Ind., and Paducah, Ky.		160	25 per 100 lbs.	25.00	3.12	1½ per 100 lbs.	10.00	1.25
Chattanooga, Tenn., and Decatur, Ala.		185	10 per 100 lbs.	10.00	1.08			
St. Louis, Mo., and Peoria, Ill.		200	25 per 100 lbs.	25.00	2.50			
Mississippi and Illinois Rivers.		200	150 per ton.	7.50	.75			
Ohio River.								
Mobile and Tombigbee Rivers.		230	20 per 100 lbs.	20.00	1.74	10 per 100 lbs.	10.00	.79
Mississippi River.		254	15 per 100 lbs.	15.00	1.18			
Ohio and Great Kanawha Rivers.		263	25½ per ton.	12.50	.95			
Mississippi and Ohio Rivers.		299	20 per 100 lbs.	20.00	1.34	10 per 100 lbs.	10.00	.67
Mobile and Alabama Rivers.		308	do.	20.00	1.30	15 per 100 lbs.	15.00	.97
Ohio and Great Kanawha Rivers.		325	25½ per ton.	12.50	.77	20½ per ton.	10.00	.62
Memphis, Tenn., and Vicksburg, Miss.		370	124 per 100 lbs.	12.50	.68	10 per 100 lbs.	10.00	.54
St. Paul, Minn., and Davenport, Iowa.		378	18 per 100 lbs.	18.00	.95			
do.		407				10 per 100 lbs.	10.00	.49
Mississippi and Missouri Rivers.		415	20 per 100 lbs.	20.00	.96	do.	10.00	.48
Mississippi River.		446	15 per 100 lbs.	15.00	.67			
do.								
<i>Pacific slope.</i>								
Between—								
Kennewick and White Bluffs, Wash.		42	10 per 100 lbs.	10.00	4.76			
Wenatchee and Brewster, Wash.		70	17½ per 100 lbs.	7.50	5.00			
San Francisco and Walnut Grove, Cal.		83	300 per ton.	15.00	3.75			
do.								
San Francisco Bay and Sacramento River.		94	do.	15.00	3.19	250 per ton.	12.50	2.66
San Francisco Bay and San Joaquin River.		112	15 per 100 lbs.	15.00	2.68	12½ per 100 lbs.	12.50	2.23
San Francisco Bay and Sacramento River.		239	42 per 100 lbs.	42.00	3.51	12 per 100 lbs.	12.00	1.00
Columbia and Willamette Rivers.								

¹ Average for 50-pound bales.² Average for 100-pound bales.

No actual average weight is available for a bale of hay, as carried over this route.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912—Continued.*

PEANUTS.

Route.	Waterway.	Dis- tance.	Freight rates.				
			On small lots, or any quantity.		On large lots, where specially quoted.		
			As quoted to shippers.	Per short ton per mile.	As quoted to shippers.	Per 100 pounds.	Per short ton per mile.
<i>Atlantic slope.</i> Between— Norfolk and Richmond, Va..... Baltimore, Md., and Norfolk, Va..... <i>Mississippi Valley, including Gulf slope.</i>	Elizabeth and James Rivers. Chestapeake Bay.....	Miles. 116 184	Cents. 21 per 100 lbs..... do.....	Cents. 3.62 2.28	Cents. 15 per 100 lbs..... do.....	Cents. 15.00 15.00	Cents. 2.59 1.63
Between— Paducah, Ky., and Britts Landing, Tenn..... Memphis, Tenn., and Paducah, Ky.....	Tennessee River..... Mississippi and Ohio Rivers.....	138 299	20 per 100 lbs..... do.....	2.90 1.34	15 per 100 lbs..... 12½ per 100 lbs.....	15.00 12.50	2.17 .84

POTATOES.

<i>Atlantic slope.</i> Between— Newburgh and Wappingers Falls, N. Y. Philadelphia, Pa., and Billingsport, N. J. Albany and New Baltimore, N. Y. Newburgh and Pourbahepsie, N. Y. Philadelphia and Chester, Pa. Philadelphia and Bridgeport, N. J. Hartford and Middletown, Conn. Burlington, Vt., and Plattsburg, N. Y. Gardner and Bath, Me. Newburgh and Haverstraw, N. Y. Jacksonville and Green Cove Springs, Fla. Philadelphia, Pa., and Wilmington, Del. Albany and Catskill, N. Y. Philadelphia, Pa., and Trenton, N. J. Burlington and St. Albans Bay, Vt.....	Hudson River..... Delaware River..... Hudson River..... do..... do..... Delaware River..... do..... Connecticut River..... Lake Champlain..... Kennebec River..... Hudson River..... St. Johns River..... Delaware River..... Hudson River..... Delaware River..... Lake Champlain.....	12 12 12 15 16 18 18 22 22 24 24 30 31 33 33 43	10 per 2½ to 3 bu. sack. 8 per 100 lbs. 1½ per barrel. do..... 8 per 100 lbs. 6 per 100 lbs. 7 per 100 lbs. 5 per 100 lbs. 8 per 100 lbs. 15 per sack. 20 per barrel. 8 per 100 lbs. 10 per barrel. 8 per 100 lbs. do.....	1 6.67 8.00 2 5.28 2 5.28 8.00 6.00 7.00 5.00 8.00 1 10.00 2 10.53 8.00 2 8.26 2 8.00 8.00	1 11.11 13.33 2 7.01 2 6.58 8.80 6.67 7.00 4.55 6.67 18.33 2 7.02 5.16 2 3.19 4.41 4.00	6 per 100 lbs. 8 per barrel. 6 per 100 lbs. 6 per 100 lbs. 6 per 100 lbs. 6 per 100 lbs. 6 per 100 lbs. 6 per 100 lbs. 6 per 100 lbs. 10 per sack. 6 per 100 lbs. 7 per 100 lbs. 7 per 100 lbs. 7 per 100 lbs. 7 per 100 lbs.	6.00 4.21 6.00 6.00 6.00 6.00 6.00 6.00 6.00 1 6.67 6.00 7.00 7.00 7.00 7.00	10.00 5.61 6.67 5.56 6.00 5.00 5.00 5.00 1 5.56 4.52 3.89
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		40	15 per 100 lbs.	15.00	7.50	12 per 100 lbs.	12.00	6.00
Lake George.....		40	15 per 100 lbs.	15.00	7.50	12 per 100 lbs.	12.00	6.00
Hartford and East Haddam, Conn.		41	8 per 100 lbs.	8.00	3.90	7 per 100 lbs.	7.00	3.41
Philadelphia, Pa., and Salem, N. J.		43	8 per 100 lbs.	8.00	3.56	6 per 100 lbs.	6.00	2.67
Philadelphia, Pa., and Delaware City, Del.		45	9 per 100 lbs.	9.00	4.00	8 per 100 lbs.	8.00	3.56
Georgetown and Conway, S. C.		46	14 per 100 lbs.	14.00	6.09	8 per 100 lbs.	8.00	3.27
Hartford and Lyme, Conn.		49	12 per 100 lbs.	12.00	4.90	8 per 100 lbs.	8.00	3.27
Philadelphia, Pa., and Frederick, Del.		90	22 per barrel.	210.53	2.34	7 per 100 lbs.	7.00	1.54
Newburgh and Troy, N. Y.		91	13 per barrel.	27.89	2.73	7 per 100 lbs.	7.00	1.54
New York and Tugersing, N. Y.		98	20 per bag.	113.83	1.72	7 per 100 lbs.	7.00	1.54
Elizabeth and James Rivers.		116	20 per barrel.	210.53	2.82	9 per 100 lbs.	9.00	1.50
Delaware River, canal, and Chesapeake Bay.		120	11 per 100 lbs.	11.00	1.83	9 per 100 lbs.	9.00	1.50
Chesapeake Bay and Wicomico River.		142	25 per barrel.	213.16	2.85	20 per bbl. of 150 lbs.	13.33	1.81
St. Johns River.		147	10 per p/g. of 50 lbs.	20.00	2.72	11 per 100 lbs.	11.00	1.36
Chesapeake Bay and Patuxent River.		150	25 per barrel.	213.16	2.75	11 per 100 lbs.	11.00	1.36
Chesapeake Bay and Nanticoke River.		160	do.	213.16	2.75	11 per 100 lbs.	11.00	1.36
Connecticut River and Long Island Sound.		162	13 per 100 lbs.	13.00	1.60	11 per 100 lbs.	11.00	1.36
Chesapeake Bay.		184	20 per flour barrel.	210.53	2.14	11 per 100 lbs.	11.00	1.36
Chesapeake Bay and York River.		195	13 per 100 lbs. in bags.	13.00	1.41	11 per 100 lbs.	11.00	1.36
Savannah River.		202	25 per barrel.	213.16	2.135	11 per 100 lbs.	11.00	1.36
Chesapeake Bay and Rappahannock River.		225	25 per sack.	116.67	1.67	11 per 100 lbs.	11.00	1.36
do.		285	25 per barrel.	213.16	2.17	11 per 100 lbs.	11.00	1.36
Altamaha and Ocmulgee Rivers.		370	7 per 100 lbs.	7.00	2.92	6 per 100 lbs.	6.00	.32
Ohio River.		25	10 per 100 lbs.	10.00	8.00	8 per 100 lbs.	8.00	3.56
Great Kanawha River.		28	4 per bushel.	46.67	4.76	8 per 100 lbs.	8.00	3.56
Ohio River.		45	10 per 100 lbs.	10.00	4.44	8 per 100 lbs.	8.00	3.56
Calcasieu River and Lake.		53	do.	10.00	3.77	8 per 100 lbs.	8.00	3.56
Great Kanawha and Ohio Rivers.		62	4 per bushel.	46.67	4.15	8 per 100 lbs.	8.00	3.56
Mississippi River.		65	15 per 100 lbs.	15.00	4.62	8 per 100 lbs.	8.00	3.56
Flint River.		69	10 per 100 lbs.	10.00	2.90	8 per 100 lbs.	8.00	3.56
Ohio River.		76	do.	10.00	2.63	8 per 100 lbs.	8.00	3.56
Mississippi River.		100	25 per barrel.	213.16	2.92	8 per 100 lbs.	8.00	3.56
do.		104	125 per 100 lbs.	12.50	2.50	20 per 100 lbs.	20.00	3.55
Tennessee River.		105	25 per 100 lbs.	25.00	4.81	10 per 100 lbs.	10.00	1.90
Mississippi River.		128	125 per 100 lbs.	12.50	2.38	20 per 100 lbs.	20.00	3.55
Ohio River.		128	35 per barrel.	27.89	2.23	20 per 100 lbs.	20.00	3.55
Tennessee River.		173	25 per 100 lbs.	25.00	3.12	20 per 100 lbs.	20.00	3.55
Apalachicola and Flint Rivers.		173	10 per 100 lbs.	10.00	1.16	20 per 100 lbs.	20.00	3.55

³ Southbound, in winter.⁴ Assuming the average weight of 1 bushel of potatoes to be 60 pounds.¹ Assuming the average gross weight of 1 sack or bag of potatoes to be 150 pounds.² Assuming the average gross weight of 1 barrel of potatoes to be 190 pounds.*Mississippi Valley, including Gulf slope.*

Between—

Shawneetown and Cave in Rock, Ill.
 Charleston and Montgomery, W. Va.
 Cairo, Ill., and Paducah, Ky.
 Lake Charles and Cameron, La.
 Charleston, W. Va., and Gallipolis, Ohio.
 Memphis, Tenn., and White Hall, Ark.
 Albany and Bainbridge, Ga.
 Shawneetown and Posiades, Ill.
 St. Louis, La., and Tip Top, Ill.
 Vicksburg and Natchez, Miss.
 Chattanooga and Kingston, Tenn.
 Memphis, Tenn., and Fruit Point, Miss.
 Cincinnati, Ohio, and Louisville, Ky.
 Chattanooga, Tenn., and Decatur, Ala.
 Apalachicola, Fla., and Bainbridge, Ga.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912—Continued.*

POTATOES—Continued.

Route.	Waterway.	Dis- tance.	On small lots, or any quantity.				On large lots, where specially quoted.			
			As quoted to shippers.	Per 100 pounds.	Per short ton per mile.	As quoted to shippers.	Per 100 pounds.	Per short ton per mile.		
<i>Mississippi Valley, including Gulf slope— Continued.</i>										
Between— Evansville, Ind., and Bowling Green, Ky.	Ohio, Green, and Big Barren Rivers...	Miles. 190	17½ per 100 lbs.	Cents. 17.50	Cents. 1.84	12½ per 100 lbs.	Cents. 12.50	Cents. 1.32		
St. Louis, Mo., and Peoria, Ill.	Mississippi and Illinois Rivers...	200	20 per 100 lbs.	20.00	2.00	15 per 100 lbs.	15.00	1.50		
Cincinnati, Ohio, and Parkersburg, W. Va.	Ohio River...	200	8 per bushel.	1 13.33	1 1.33					
Memphis, Tenn., and Arkansas City, Ark.	Mississippi River...	209	20 per 100 lbs.	20.00	1.91	15 per 100 lbs.	15.00	1.44		
Mobile and Demopolis, Ala.	Mobile and Tombigbee Rivers...	230	25 per barrel.	2 13.16	2 1.14					
Memphis, Tenn., and Cairo, Ill.	Mississippi River...	254	15 per 100 lbs.	15.00	1.18	12½ per 100 lbs.	12.50	.98		
Cincinnati, Ohio, and Charleston, W. Va.	Ohio and Great Kanawha Rivers...	263	25 per barrel.	2 13.16	2 1.00					
Mobile and Selma, Ala.	Mobile and Alabama Rivers...	308	20 per sack.	3 13.33	3 .87					
Pittsburgh, Pa., and Charleston, W. Va.	Ohio and Great Kanawha Rivers...	325	25 per barrel.	2 13.16	2 .81	20 per barrel.	10.53	.65		
New Orleans and Harrisonburg, La.	Mississippi, Red, and Black Rivers...	340	30 per 100 lbs.	30.00	1.76	20 per 100 lbs.	20.00	1.18		
Apalachicola, Fla., and Columbus, Ga.	Apalachicola and Flint Rivers...	360	15 per 2½ bushels.	1 10.00	1 .55					
Vicksburg, Miss., and Memphis, Tenn.	Mississippi River...	370	10 per 100 lbs.	10.00	.54					
St. Paul, Minn., and Davenport, Iowa.	do.	378	18 per 100 lbs.	18.00	.95					
St. Louis and Kansas City, Mo.	Mississippi and Missouri Rivers...	407	28 per 100 lbs.	28.00	1.38	22 per 100 lbs.	22.00	1.08		
New Orleans, La., and Carriola, Ark.	Mississippi River...	446	15 per sack.	2 10.00	3 .45					
Cincinnati, Ohio, and Pittsburgh, Pa.	Ohio River...	470	20 per barrel.	2 10.53	2 .45	15 per barrel.	7 .89	2 .34		
Memphis, Tenn., and Cincinnati, Ohio.	Mississippi and Ohio Rivers...	749	22½ per 100 lbs.	22.50	.00	18½ per 100 lbs.	18.50	.49		
<i>Pacific slope.</i>										
Between— Wenatchee and Bridgeport, Wash.	Columbia River...	79	15 per 100 lbs.	15.00	3.80					
San Francisco and Walnut Grove, Cal.	San Francisco Bay and Sacramento River.	80	10 per sack (120 lbs.)	8.33	2.08	8 per sack (120 lbs)	6.67	1.67		
San Francisco and Stockton, Cal.	San Francisco Bay and San Joaquin River.	94	do.	8.33	1.77	8 per sack (120 lbs)	6.67	1.42		
San Francisco and Sacramento, Cal.	San Francisco Bay and Sacramento River.	112	12 per 100 lbs.	12.00	2.14					

RICE, ROUGH (UNHULLED).

Between— <i>Atlantic slope.</i> Georgetown and Conway, S. C..... Georgetown and Cains Landing, S. C.... <i>Mississippi Valley, including Gulf slope.</i>	Wacamaw River..... Peedee River.....	45 83	10 per 100 lbs. 10 per sack.....	10.00 4 5.56	4.35 4 1.29			
Between— Lake Charles and Cameron, La..... New Orleans and Donaldsonville, La.... New Orleans and Bayou Teche land- ings, La. ⁶ New Orleans and Harrisonburg, La.....	Calcasieu River and Lake..... Mississippi River..... Mississippi River, Bayou Teche, and connecting waterways. Mississippi, Red, and Black Rivers.....	53 79 { 6 175 6 240 340	10 per 100 lbs. ⁶ 15 per 100 lbs. ⁶ 10 per 100 lbs. 13 per 100 lbs. 15 per 100 lbs. 25 per 100 lbs.....	10.00 15.00 10.00 13.00 15.00 25.00	3.77 5.66 2.53 1.49 1.25 1.47	5 per 100 lbs..... 10 per 100 lbs..... 8 per 100 lbs..... 12 per 100 lbs..... 15 per 100 lbs.....	5.00 10.00 8.00 12.00 15.00	1.89 3.77 2.03 1.00 1.88

SUGAR.

Between— <i>Mississippi Valley, including Gulf slope.</i> New Orleans and Donaldsonville, La.... New Orleans and Bayou Teche land- ings, La. ⁶	Mississippi River..... Mississippi River, Bayou Teche, and connecting waterways.	79 { 6 175 6 240	15 per 100 lbs. 9 per 100 lbs. 15 per 100 lbs.....	15.00 9.00 15.00	3.80 1.03 1.25	10 per 100 lbs..... 11 per 100 lbs.....	10.00 11.00	2.82 .92

TOBACCO, UNMANUFACTURED.

Between— <i>Atlantic slope.</i> Philadelphia, Pa., and Delaware City, Del..... Norfolk and Richmond, Va..... Philadelphia, Pa., and Baltimore, Md.... <i>Mississippi Valley, including Gulf slope.</i>	Delaware River..... Elizabeth and James Rivers..... Delaware River, canal, and Chesapeake Bay.	45 116 120	11 per 100 lbs..... 10 per 100 lbs. ⁷ 11 per 100 lbs.....	11.00 10.00 11.00	4.89 1.72 1.83	9 per 100 lbs.....	9.00	4.00
Between— Cincinnati, Ohio, and Louisville, Ky.... Evansville, Ind., and Bowling Green, Ky.	Ohio River..... Ohio, Green, and Big Barren Rivers.....	128 190	150 per hhd. 20 per 100 lbs.....	8 8.67 20.00	8 1.36 2.11	100 per hhd.....	8 5.78	8 90

¹ Assuming the average weight of 1 bushel of potatoes to be 60 pounds.² Assuming the average gross weight of 1 barrel of potatoes to be 190 pounds.³ Assuming the average weight of 1 sack of potatoes to be 150 pounds.⁴ Assuming the average weight of 1 sack of rice to be 180 pounds.⁵ These quotations are from different boats.⁶ Average distance, as reported. Distance varies greatly, according to route.⁷ In casks, hogsheds, or tierces.⁸ Assuming average gross weight of 1 hogshedd of tobacco in this Ohio River trade to be 1,730 pounds.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912—Continued.*

VEGETABLES, OTHER THAN POTATOES.

Route.	Waterway.	Dis- tance.	Freight rates.					
			On small lots, or any quantity.			On large lots, where specially quoted.		
			As quoted to shippers	Per 100 pounds.	Per short ton per mile.	As quoted to shippers.	Per 100 pounds.	Per short ton per mile.
<i>Atlantic slope.</i>			<i>Miles.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Between—	Hudson River.....	12	10 per 100 lbs.	10.00	16.67			
Newburgh and Wappinger Falls, N. Y.	Delaware River.....	18	8 per 100 lbs.	8.00	8.89	6 per 100 lbs.	6.00	6.67
Philadelphia and Chester, Pa.	Connecticut River.....	20	13 per 100 lbs.	13.00	13.00	7 per 100 lbs.	7.00	7.00
Hartford and Middletown, Conn.	Kennebec River.....	24	15 per 100 lbs.	15.00	12.50			
Gardiner and Bath, Me.	Delaware River.....	31	12 per 100 lbs.	12.00	7.74	8 per 100 lbs.	8.00	8.00
Philadelphia, Pa., and Wilmington, Del.	do.....	36	9, 10, or 12 per 100 lbs.	10.33	5.74	7 or 8 per 100 lbs.	17.50	5.16
Philadelphia, Pa., and Trenton, N. J.	Lake George.....	40	20 per 100 lbs.	20.00	10.00			4.17
Lake George and Baldwin, N. Y.	Connecticut River.....	41	14 per 100 lbs.	14.00	6.83	8 per 100 lbs.	8.00	3.90
Hartford and East Haddam, Conn.	Delaware River.....	45	15 per 100 lbs.	15.00	6.67	9 per 100 lbs.	9.00	4.00
Philadelphia, Pa., and Delaware City, Del.	Connecticut River.....	49	16 per 100 lbs.	16.00	6.53	do.....	9.00	3.67
Hartford and Lyme, Conn.	Hudson River.....	91	19 per 100 lbs.	19.00	4.18			
Newburgh and Troy, N. Y.	Tohopekaliga Lake and Kissimmee River and Lake.....	100	10 per crate 2	20.00	4.00			
Kissimmee and Fort Bassenger, Fla.								
Norfolk and Richmond, Va.	Elizabeth and James Rivers.....	116	13 per 100 lbs.	13.00	2.24			
Philadelphia, Pa., and Baltimore, Md.	Delaware River, canal, and Chesapeake Bay.....	120	22 per 100 lbs.	22.00	3.67	11 per 100 lbs.	11.00	1.83
Jacksonville and Sanford, Fla.	St. Johns River.....	147	10 per crate of 50 lbs.	20.00	2.72	20 per 150 lbs.	13.33	1.81
Hartford, Conn., and New York, N. Y.	Connecticut River and Long Island Sound.....	162	22 per 100 lbs.	22.00	2.72	13 per 100 lbs.	13.00	1.60
Baltimore, Md., and Norfolk, Va.	Chesapeake Bay.....	184	25 per 100 lbs.	25.00	2.72			
Brunswick and Macon, Ga.	Altamaha and Ocmulgee Rivers.....	370	8 per 100 lbs.	8.00	.43	7 per 100 lbs.	7.00	.38
<i>Mississippi Valley, including Gulf slope.</i>								
Between—								
Shawneetown and Cave in Rock, Ill.	Ohio River.....	25	10 per 100 lbs.	10.00	8.00			
Cairo, Ill., and Paducah, Ky.	do.....	45	15 per 100 lbs.	15.00	6.67			4.44
Lake Charles and Cameron, La.	Calcasieu River and Lake.....	53	15 per 100-lb. crate.	15.00	5.66	10 per 100 lbs.	10.00	
Charleston, W. Va., and Gallipolis, Ohio.	Great Kanawha and Ohio Rivers.....	62	150 per ton	7.50	2.42	125 per ton	6.25	2.02
Memphis, Tenn., and White Hall, Ark.	Mississippi River.....	65	25 per 100 lbs.	25.00	7.69			
Albany and Bainbridge, Ga.	Flint River.....	69	15 per 130 lbs.	15.00	4.35			

	Ohio River	12 or 15 per 100 lbs.	12 per 100 lbs.	3.55	12.00	3.16
Shawneetown and Rosiclare, Ill.	Mississippi River	25 per 100 lbs.	23.50	5.00	20.00	3.85
Vicksburg and Natchez, Miss.	Tennessee River	25 per 100 lbs.	23.00	4.81	20.00	2.29
Chattanooga and Kingston, Tenn.	Mississippi River	25 per 100 lbs.	22.50	3.12	20.00	2.50
Memphis, Tenn., and Friar Point, Miss.	Tennessee River	25 per 100 lbs.	23.00	1.16	15.00	1.58
Chattanooga, Tenn., and Decatur, Ala.	Apalachicola and Flint Rivers	10 per 100 lbs.	20.00	2.11	20.00	1.91
Apalachicola, Fla., and Bainbridge, Ga.	Ohio, Green, and Big Barren Rivers	20 per 100 lbs.	25.00	2.39	20.00	1.13
Evansville, Ind., and Bowling Green, Ky.	Mississippi River	25 per 100 lbs.	26.50	2.09	15.00	1.18
Memphis, Tenn., and Arkansas City, Ark.	do.	25 per 100 lbs.	30.00	1.76	20.00	1.18
Memphis, Tenn., and Cairo, Ill.	Ohio and Great Kanawha Rivers	25 per 100 lbs.	25.00	1.39	15.00	.81
Cincinnati, Ohio, and Charleston, V. Va.	Mississippi, Red, and Black Rivers	25 per 100 lbs.	22.50	1.22	22.00	1.08
New Orleans and Harrisonburg, La.	Apalachicola and Chattahoochee Rivers	25 per 100 lbs.	17.50	.93	15.00	.64
Apalachicola, Fla., and Columbus, Ga.	Mississippi River	15 or 20 per 100 lbs.	48.00	2.36	22.00	1.08
Vicksburg, Miss., and Memphis, Tenn.	do.	30 per 100 lbs.	30.00	1.28	15.00	.64
St. Paul, Minn., and Davenport, Iowa.	Mississippi and Missouri Rivers	30 per 100 lbs.	30.00			
St. Louis and Kansas City, Mo.	Ohio River					
Cincinnati, Ohio, and Pittsburgh, Pa.						

WHEAT.

<i>Atlantic slope.</i>									
Between— Philadelphia and Chester, Pa. Philadelphia, Pa., and Wilmington, Del. Philadelphia, Pa., and Salem, N. J. Philadelphia, Pa., and Delaware City, Del. Washington, D. C., and Mount Holly, Va. Philadelphia, Pa., and Frederica, Del. Philadelphia, Pa., and Baltimore, Md. Baltimore and Salisbury, Md. Baltimore and Bristol, Md. Baltimore, Md., and Seaford, Del. Baltimore, Md., and Norfolk, Va. Baltimore, Md., and West Point, Va. Baltimore, Md., and Tappahannock, Va. Baltimore, Md., and Fredericksburg,	Delaware River.	18 31	5 per 100 lbs. 6 per 100 lbs.	5.00 6.00	5.56 3.87	4 per 100 lbs. 5 per 100 lbs.	4.00 5.00	4.44 3.23	
	do.								
	do.	45	8 per 100 lbs.	8.00	3.56	6 per 100 lbs.	6.00	2.61	
	do.	45	do.	8.00	3.56	7 per 100 lbs.	7.00	3.11	
	Potomac River.	84	4 per bushel.	3.67	1.59				
	Delaware River and Murder Kill Creek	90	3 per bushel.	5.00	1.11				
	Delaware River, canal, and Chesapeake Bay.	120	9 per 100 lbs.	9.00	1.50	8 per 100 lbs.	8.00	1.33	
	Chesapeake Bay and Wicomico River.	142	4 per bushel.	3.67	.94				
	Chesapeake Bay and Patuxent River.	150	5 per bushel.	3.33	1.11				
	Chesapeake Bay and Nantuxet River.	160	4 per bushel.	3.67	.83				
	Chesapeake Bay.	184	10 per 100 lbs.	10.00	1.09	7 per 100 lbs.	7.00	.76	
	Chesapeake Bay and York River.	195	do.	10.00	1.03	do.	7.00	.72	
	Chesapeake Bay and Rappahannock River.	225	5 per bushel.	8.33	.74				
	do.	285	do.	8.33	.58				

1 Mean of quotations given.

2 Assuming the average weight of 1 crate of vegetables to be 50 pounds.

3 Assuming the average weight of 1 bushel of wheat to be 60 pounds.

TABLE 2.—*Freight rates by boat on various farm products during September and October, 1912—Continued.*

WHEAT—Continued.

Route.	Waterway.	Dis- tance.	Freight rates.			
			On small lots, or any quantity.		On large lots, where specially quoted.	
			As quoted to shippers.	Per 100 pounds.	As quoted to shippers.	Per 100 pounds.
						Per short ton per mile.
<i>Mississippi Valley, including Gulf slope.</i>						
Between—	Shawneetown and Cave in Rock, Ill.	Miles.	Cents.	Cents.	Cents.	Cents.
	Charleston and Montgomery, W. Va.	25	10.00	8.00		
	Cairo, Ill., and Paducah, Ky.	28	15.00	3.57		
	Charleston, W. Va., and Gallipolis, Ohio	45	8.00	3.56		
	Shawneetown and Rosiclare, Ill.	62	14.17	1.39		
	St. Louis, Mo., and Rip Rap, Ill.	76	15.83	1.88		
	Chatanooga and Kingston, Tenn.	90	5.00	1.22		
	St. Louis and Louisiana, Mo.	104	8.00	1.78		
	Evansville, Ind., and Paducah, Ky.	107	25.00	4.81		
	Bismarck and Williston, N. Dak.	137	8.00	1.50		
	Evansville, Ind., and Decatur, Ala.	150	6.00	.88		
	Chattanooga, Tenn., and Decatur, Ala.	160	8.00	1.07		
	St. Louis, Mo., and Peoria, Ill.	185	25.00	3.12		
	Cincinnati, Ohio, and Charleston, W. Va.	200	6.00	.65		
	Memphis, Tenn., and Paducah, Ky.	263	12.50	1.25		
	Pittsburgh, Pa., and Charleston, W. Va.	299	18.33	1.63		
	St. Paul, Minn., and Davenport, Iowa.	325	9.00	.60		
	St. Louis and Kansas City, Mo.	378	10.00	.62		
	Memphis, Tenn., and St. Louis, Mo.	407	18.00	.95		
	Memphis, Tenn., and Cincinnati, Ohio.	415	10.00	.48		
	Memphis, Tenn., and Cincinnati, Ohio.	749	13.50	.36		
<i>Pacific slope.</i>						
Between—	Columbia River.	42	10.00	4.76		
	Kennewick and White Bluffs, Wash.	79	30.00	6.33		
	San Francisco Bay and Sacramento River.	80	10.00	2.50		
	San Francisco and Walnut Grove, Cal.					

San Francisco and Stockton, Cal.....	San Francisco Bay and San Joaquin River.....	94	180 per ton.....	9.00	1.91	125 per ton ²	6.25	1.33
San Francisco and Sacramento, Cal....	San Francisco Bay and Sacramento River.....	112	200 per ton.....	10.00	1.79	125 per ton.....	4.50	.96
Kennewick, Wash., and Portland, Oreg.	Columbia and Willamette Rivers.....	239	37 per 100 lbs.....	37.00	3.10	12 per 100 lbs.....	6.25	1.12
							12.00	1.00

WOOL.

Between— Hartford, Conn., and New York, N. Y.	Connecticut River and Long Island Sound.	162	22 per 100 lbs.....	22.00	2.72	19 per 100 lbs.....	19.00	2.35
<i>Mississippi Valley, including Gulf slope.</i>								
Between— Charleston and Montgomery, W. Va....	Great Kanawha River.....	28	10 per 100 lbs.....	10.00	7.14			
Charleston, W. Va., and Gallipolis, Ohio	Great Kanawha and Ohio Rivers.....	62	15 per 100 lbs. ²	15.00	4.84			
St. Louis, Mo., and Rip Rap, Ill.....	Mississippi River.....	90	25 per 100 lbs. ²	25.00	8.06			
Paducah, Ky., and Britf Landing, Tenn.	Tennessee River.....	138	35 per 100 lbs.....	35.00	5.56			
Evansville, Ind., and Bowling Green, Ky.	Ohio, Green, and Big Barren Rivers..	190	20 per 100 lbs.....	20.00	5.07	20 per 100 lbs.....	20.00	2.90
Cincinnati, Ohio, and Parkersburg, W. Va.	Ohio River.....	200	15 per 100 lbs.....	15.00	2.11			
Cincinnati, Ohio, and Charleston, W. Va.	Ohio and Great Kanawha Rivers.....	263	25 per 100 lbs.....	25.00	1.50			
Pittsburgh, Pa., and Charleston, W. Va.	do.....	325	40 per 100 lbs.....	40.00	2.46			
Cincinnati, Ohio, and Pittsburgh, Pa..	Ohio River.....	470	30 per 100 lbs.....	30.00	1.28	25 per 100 lbs.....	25.00	1.06
<i>Pacific slope.</i>								
Between— Kennewick and White Bluffs, Wash....	Columbia River.....	42	20 per 100 lbs.....	20.00	9.52			
Kennewick, Wash., and Portland, Oreg.	Columbia and Willamette Rivers.....	239	42 per 100 lbs.....	42.00	3.51	31 per 100 lbs.....	31.00	2.59

¹ Assuming the average weight of 1 bushel of wheat to be 60 pounds and 1 sack to contain an average of 2 bushels.² These quotations are from different boats.

TABLE 3.—Comparison of freight rates by water and by rail over selected routes for September and October, 1912.

[Sources: Rates by water reported by representatives of steamboats and steamboat lines; rates by rail reported by the Division of Tariffs, Interstate Commerce Commission.]

Water.		Rail.			
Route, distance, and commodity.		Freight rate.		Freight rate.	
		Per 100 pounds.	Per short ton per mile.	Per 100 pounds.	Per short ton per mile.
		Amount.	Excess over water.	Amount.	Excess over water.
<i>Between Hartford, Conn., and New York, N. Y. (152 miles).</i>					
Apples:		Cents.		Cents.	Cents.
Less than carload.....		16.00		16.00	2.91
Carload.....		11.00		11.00	2.00
Eggs: Any quantity.....		19.00		19.00	3.45
Hay:					
Less than carload.....		22.00		22.00	4.00
Carload.....		11.00		11.00	2.00
Potatoes:					
Less than carload.....		13.00		13.00	2.36
Carload.....		11.00		11.00	2.00
<i>Between Cincinnati, Ohio, and Pittsburgh, Pa. (170 miles).</i>					
Apples:					
Under 24,000 pounds.....		1 12.58	1.54	26.00	13.42
24,000 pounds and over.....		19.43	1.40	15.00	6.57
Eggs: Any quantity.....		\$ 28.30	\$ 1.20	35.00	6.70
Potatoes:					
Under 24,000 pounds.....		\$ 10.53	3.45	18.00	7.47
24,000 pounds and over.....		\$ 7.89	3.34	15.00	7.11
Wool:					
Under 24,000 pounds.....		30.00	1.28	41.00	11.00
24,000 pounds and over.....		25.00	1.06	26.00	1.00
<i>Between Cincinnati, Ohio, to Pittsburgh, Pa. (311 miles).</i>					
Apples:					
Less than carload.....					
Carload.....					
Eggs: Any quantity.....					
Potatoes:					
Less than carload.....					
Carload.....					
Wool:					
Less than carload.....					
Carload.....					

Between Cincinnati, Ohio, and Charleston, W. Va. (283 miles).

Apples: Any quantity.....	1 1.20	1 15.72	<i>Charleston, W. Va., to Cincinnati, Ohio (211 miles).</i>			
Less than carload.....			Apples:			
Eggs: Any quantity.....	2 2.87	2 37.74	Carload.....	22.00	6.28	.80
Hay: Any quantity.....	.95	12.50	Eggs: Any quantity.....	28.50	43.72	4.06
			Hay:		49.24	4.17
			Less than carload.....	22.00	9.50	1.14
Potatoes: Any quantity.....	3 1.00	3 13.16	Carload.....	12.00	4.50	.19
			Potatoes:			
			Less than carload.....	15.00	1.84	.42
			Carload.....	12.00	41.16	.14
			<i>Cincinnati, Ohio, to Memphis, Tenn. (194 miles).</i>			
Eggs: Less than carload.....	2 2.02	2 75.47	Eggs: Any quantity.....	60.00	415.47	.21
Potatoes:			Potatoes:			
Less than carload.....	.60	22.50	Carload.....	30.00	7.50	.61
Carload.....	.49	18.50	Less than carload.....	26.00	7.50	.58
Wheat:			Carload.....			
Less than carload.....	.36	13.50	Wheat:			
Carload.....	.27	10.00	Less than carload.....	17.00	3.50	.33
			Carload.....		7.00	.42
			<i>St. Louis, Mo., to Memphis, Tenn. (322 miles).</i>			
Apples:			Apples:			
Less than carload.....	1.91	118.87	Less than carload.....	25.00	6.13	.64
Carload.....	1.61	112.28	Carload.....	22.00	9.42	.76
Eggs: Any quantity.....	2 3.18	2 66.04	Eggs: Any quantity.....	50.00	416.04	4.07
Hay:			Hay:			
Less than carload.....	.96	20.00	Less than carload.....	30.00	10.00	.90
Carload.....	.48	10.00	Carload.....	12.00	2.00	.27
Wheat: Any quantity.....	.48	10.00	Wheat:			
			Less than carload.....	12.00	2.00	.75
			Carload.....	11.00	1.00	.20

¹ Computed from a quoted rate per barrel, assuming average gross weight of 1 barrel of apples to be 159 pounds.

² Computed from a quoted rate per case (30 dozen), assuming the average weight of 1 case to be 53 pounds.

³ Computed from a quoted rate per barrel, assuming the average gross weight of 1 barrel of potatoes to be 190 pounds.

Excess of water rate over rail rate.

TABLE 4.—*Distance and time of transit over selected river routes in the United States during September and October, 1912.*

[Sources: Distances chiefly as reported by the Chief of Engineers, War Department; time of transit as reported by representatives of steamboats or steamboat lines.]

Route.	Miles.	Hours.	Miles per hour.
<i>Atlantic slope.</i>			
<i>Between—</i>			
Newburgh and Wappingers Falls, N. Y.	12	1.50	8.0
Philadelphia, Pa., and Billingsport, N. J.	12	1.00	12.0
New Baltimore and Albany, N. Y.	15	1.75	8.6
Newburgh and Poughkeepsie, N. Y.	16	3.00	5.3
Philadelphia, Pa., and Bridgeport, N. J.	18	2.00	9.0
Philadelphia and Chester, Pa.	18	1.50	12.0
Hartford and Middletown, Conn.	20	2.00	10.0
Burlington, Vt., and Plattsburg, N. Y.	22	1.50	14.7
Gardiner and Bath, Me.	24	2.50	9.6
Newburgh and Haverstraw, N. Y.	24	4.00	6.0
Jacksonville and Green Cove Springs, Fla.	30	4.00	7.5
Philadelphia, Pa., and Wilmington, Del.	31	2.00	15.5
Albany and Catskill, N. Y.	33	3.50	9.4
Philadelphia, Pa., and Trenton, N. J.	36	3.00	12.0
Burlington and St. Albans Bay, Vt.	40	3.50	11.4
Lake George and Baldwin, N. Y.	40	3.00	13.3
Hartford and East Haddam, Conn.	41	3.75	10.9
Philadelphia, Pa., and Salem, N. J.	45	4.00	11.2
Philadelphia, Pa., and Delaware City, Del.	45	4.00	11.2
Georgetown and Conway, S. C.	46	8.00	5.8
Hartford and Lyme, Conn.	49	5.00	9.8
Jacksonville and St. Augustine, Fla.	53	12.00	4.8
Savannah, Ga., and Beaufort, S. C.	60	7.00	8.6
Washington, D. C., and Mount Holly, Va.	84	18.00	4.7
Georgetown, S. C., and Cains Landing—Peedee River	86	24.00	3.6
Philadelphia, Pa., and Frederica, Del.	90	10.00	9.0
Newburgh and Troy, N. Y.	91	11.00	8.3
New York and Saugerties, N. Y.	98	10.00	9.8
Kissimmee and Fort Bassenger, Fla.	100	48.00	2.1
Norfolk and Richmond, Va.	116	12.00	9.7
Baltimore, Md., and Philadelphia, Pa.	120	12.00	10.0
Baltimore and Salisbury, Md.	142	15.00	9.5
Jacksonville and Sanford, Fla.	147	18.00	8.2
Baltimore and Bristol, Md.	150	24.00	6.2
Baltimore, Md., and Seaford, Del.	160	16.00	10.0
Hartford, Conn., and New York, N. Y.	162	14.00	11.6
Baltimore, Md., and Norfolk, Va.	184	12.50	14.7
Baltimore, Md., and West Point, Va.	195	15.00	13.0
Savannah and Augusta, Ga.	202	84.00	2.4
Baltimore, Md., and Tappahannock, Va.	225	17.00	13.2
Baltimore, Md., and Fredericksburg, Va.	235	40.00	7.1
Macon and Brunswick, Ga.	370	36.00	10.3
<i>Mississippi River and tributaries, including Gulf slope.</i>			
<i>Between—</i>			
Memphis, Tenn., and Mount City, Ark.	4	1.00	4.0
Shawneetown and Cave in Rock, Ill.	25	6.00	4.2
Charleston and Montgomery, W. Va.	28	10.00	2.8
Cairo, Ill., and Paducah, Ky.	45	4.00	11.2
Lake Charles and Cameron, La.	53	7.00	7.6
Alton and Hamburg, Ill.	54	30.00	1.8
Charleston, W. Va., and Gallipolis, Ohio.	62	12.00	12.6
Memphis, Tenn., and White Hall, Ark.	65	10.00	16.2
Albany and Bainbridge, Ga.	69	12.00	5.4
Shawneetown and Rosiclare, Ill.	76	10.00	5.8
New Orleans and Donaldsonville, La.	79	18.00	7.6
St. Louis, Mo., and Rip Rap, Ill.	90	48.00	4.4
St. Louis, Mo., and Hamburg, Ill.	90	48.00	1.9
Vicksburg and Natchez, Miss.	100	36.00	1.9
Chattanooga and Kingston, Tenn.	104	40.00	2.8
Memphis, Tenn., and Friar Point, Miss.	105	12.00	2.6
St. Louis and Louisiana, Mo.	107	12.00	8.8
Cincinnati, Ohio, and Louisville, Ky.	128	12.00	8.9
Evansville, Ind., and Paducah, Ky.	137	15.00	10.7
Britts Landing, Tenn., and Paducah, Ky.	138	36.00	8.5
Chattanooga, Tenn., and Decatur, Ala.	160	24.00	3.8
Apalachicola, Fla., and Bainbridge, Ga.	173	96.00	5.8
Evansville, Ind., and Louisville, Ky.	185	16.00	1.7
		30.00	10.8
			6.2

¹ These quotations are from different boats.² Downstream.³ Upstream.

TABLE 4.—Distance and time of transit over selected river routes in the United States during September and October, 1912—Continued.

Route.	Miles.	Hours.	Miles per hour.
<i>Mississippi River and tributaries, including Gulf slope—Continued.</i>			
Between—			
Bowling Green, Ky., and Evansville, Ind.....	190	30.00	6.3
St. Louis, Mo., and Peoria, Ill.....	200	30.00	6.7
Cincinnati, Ohio, and Parkersburg, W. Va.....	200	24.00	8.3
Memphis, Tenn., and Arkansas City, Ark.....	209	30.00	7.0
Mobile and Demopolis, Ala.....	230	48.00	4.8
New Orleans and Bayou Teche, La.....	¹ 240	40.00	6.0
Memphis, Tenn., and Cairo, Ill.....	254	38.00	6.7
Charleston, W. Va., and Cincinnati, Ohio.....	263	48.00	5.5
Memphis, Tenn., and Paducah, Ky.....	299	46.00	6.5
Mobile and Selma, Ala.....	308	72.00	4.3
Charleston, W. Va., and Pittsburgh, Pa.....	325	² 48.00	² 6.8
		³ 72.00	³ 4.5
New Orleans and Harrisonburg, La.....	340	150.00	2.3
Columbus, Ga., and Apalachicola, Fla.....	360	132.00	2.7
Vicksburg Miss., and Memphis, Tenn.....	370	72.00	5.1
St. Paul, Minn., and Davenport, Iowa.....	378	60.00	6.3
Kansas City and St. Louis, Mo.....	407	² 40.00	² 10.2
		³ 60.00	³ 6.8
Memphis, Tenn., and St. Louis, Mo.....	415	72.00	5.8
New Orleans, La., and Carriola, Ark.....	446	84.00	5.3
Cincinnati, Ohio, and Pittsburgh, Pa.....	470	84.00	5.6
Cincinnati, Ohio, and Memphis, Tenn.....	749	108.00	6.9
<i>Pacific slope.</i>			
Between—			
Kennewick and White Bluff, Wash.....	42	8.00	5.2
Brewster and Wenatchee, Wash.....	70	² 7.00	² 10.0
		³ 13.00	³ 5.4
Wenatchee and Bridgeport, Wash.....	79	² 8.00	² 9.9
		³ 20.00	³ 4.0
San Francisco and Walnut Grove, Cal.....	80	8.00	10.0
San Francisco and Stockton, Cal.....	94	12.00	7.8
San Francisco and Sacramento, Cal.....	112	12.00	9.3
Kennewick, Wash., and Portland, Oreg.....	239	30.00	8.0

¹ Boat routes from New Orleans to St. Martinsville range from 174 to 257 miles.² Downstream.³ Upstream.

TABLE 5.—Number of intermediate landings and average distance between landings over selected routes.

Route.	Number of intermediate landings, as reported.	Miles.	Average miles between landings.
Between—			
Cincinnati, Ohio, and Memphis, Tenn.....	346	749	2.16
St. Louis, Mo., and Memphis, Tenn.....	313	415	1.30
St. Louis, Mo., and Waterloo, Ala.....	267	513	1.91
Apalachicola, Fla., and Columbus, Ga.....	246	360	1.46
Pittsburgh, Pa., and Cincinnati, Ohio.....	141	470	3.31
Evansville, Ind., and Bowling Green, Ky.....	71	190	2.64
Baltimore, Md., and Fredericksburg, Va.....	34	285	8.38
			¹ 3.12
Hartford, Conn., and New York, N. Y.....	12	162	12.50
			¹ 4.33
Baltimore, Md., and Seaford, Del.....	12	160	12.31
			13.42
Baltimore, Md., and Norfolk, Va.....	1	184	92.00

¹ Average for part of route on which the group of intermediate landings are located. Distances: Hartford to mouth of Connecticut River, about 52 miles; Fredericksburg to mouth of Rappahannock River, about 106 miles; Seaford to mouth of Nanticoke River, about 41 miles.

TABLE 6.—*Summary of average rates of speed of steamboats on inland waterways.*

Rate, miles per hour.	Number of average rates reported.			
	Atlantic slope.	Mississippi Valley, including Gulf slope.	Pacific slope.	Total.
Less than 4.....	3	12	0	15
4 and less than 6.....	4	15	3	22
6 and less than 8.....	4	14	1	19
8 and less than 10.....	13	5	3	21
10 and less than 12.....	9	4	2	15
12 and over.....	10	0	0	10
Total.....	43	50	9	102

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(PROFESSIONAL PAPER.)

ALFALFA SEED PRODUCTION; POLLINATION STUDIES.

By C. V. PIPER, *Agrostologist in Charge*, and MORGAN W. EVANS, ROLAND McKEE,
and W. J. MORSE, *Scientific Assistants, Forage-Crop Investigations*.

INTRODUCTION.

For a number of years past it has been a conspicuous fact that in sections where alfalfa seed is grown commercially the yield varies greatly from season to season. Particularly striking examples of this variation in yield have occurred in the Milk River Valley of Montana, where in some seasons yields of 10 to 12 bushels per acre have been obtained, while in other years the crop was almost a complete failure. It has been generally supposed that the visit of certain insects to the flowers is absolutely necessary in order to effect pollination. In accordance with this belief, some have held that small crops of alfalfa seed were due to an unsatisfactory number of pollinating insects, while others have suggested that thrips or other destructive agencies might be accountable.

In view of the importance of the matter to alfalfa seed growers, investigations of this subject were undertaken, beginning with the season of 1906. These investigations have been conducted during subsequent seasons at various stations and have resulted in the accumulation of a mass of data which throw new light on the subject. Incidentally they have revealed the fact that the problem is much more complex than had been anticipated, and there is need of much further work, especially in the careful correlation of climatic data, as well as the abundance of insects, with the seed yields from season to season. The facts herein set forth substantiate the previous belief in the importance of insect visitors, but also show that, under certain climatic conditions, automatic self-pollination of the flower takes place. The amount of self-pollination varies from season to season and with individual plants. Whether self-pollination is sufficient to produce satisfactory seed yields is still a matter of doubt, but the observations at Chinook, Mont., indicate that at that locality this is the most probable explanation.

NOTE.—This bulletin deals with the biological problems concerned in the pollination and fecundation of the alfalfa flower. It is intended primarily for technical agronomists and botanists.

Observations at the same place also indicate that the factors or conditions which favor seed production vary during the season, as shown by the distribution of pods on mature plants. For instance, in the latter part of August, 1910, a great many plants could be found on which the earliest racemes to develop in the spring, located at the base of the plant, produced large numbers of pods. A little higher on the plant most of the flower stalks were almost or entirely bare of pods. Still higher on the stem there were a number of large, well-filled clusters of pods, indicating that for a period of two weeks or more preceding August 20 a very large proportion of the flowers had developed pods. Near the tip of the stems nearly all of the flowers fell off, leaving the stem almost bare of pods. It is probable that this variation in seed production at different periods during the season was due, directly or indirectly, to climatic conditions.

At Arlington farm, Virginia, it has frequently been observed that a large proportion of the pods fail to set, even when the flowers have been artificially tripped. While this is especially true of the flowers of the first crop of alfalfa, it seems to be due more to adverse climatic conditions than to the vigor of the plants.

PREVIOUS INVESTIGATIONS OF THE STRUCTURE AND POLLINATION OF THE ALFALFA FLOWER.

According to Urban, the peculiar structure of the alfalfa flower by which it trips, or explodes, when visited by certain insects was known in the time of Linnæus. The first explanation of the process of explosion is apparently that of DeCandolle,¹ in 1832. DeCandolle states that the explosion of the flower takes place when a certain stage of its maturity is reached.

Hildebrand,² in 1866, gives a brief general account of the structure of the alfalfa flower, comparing it with both *Indigofera* and *Cytisus*. He clearly recognizes that the peculiar mechanism of the flower is an adaptation for pollination by insects, but states that inclosed flowers finally trip in the course of their development without the help of insects. Apparently he considers that fertilization may also take place in untripped flowers, as the pollen may fall on the stigma. His observations were made in Germany.

In November, 1865, Henslow³ presented a paper before the Linnæan Society of London, which, however, was not published until 1867. Henslow studied carefully the structure of the alfalfa flower with a view of locating the explosive force. This he attributed to the elasticity of the staminal tube, but he was uncertain whether the

¹ DeCandolle, A. P. de. *Physiologie Végétale*, t. 2, Paris, 1832, p. 548.

² Hildebrand, E. Ueber die Vorrichtungen an einigen Blüten zur Befruchtung durch Insektenhülle. *Botanische Zeitung*, Jahrg. 24, No. 10, p. 75, 1866.

³ Henslow, George. Notes on the structure of *Medicago sativa*, as apparently affording facilities for the interesting of visiting insects. *Journal, Linnæan Society, Botany*, v. 9, p. 327-329, 1867.

curvature is due to the contraction of the cells on the upper side or the distension of those on the convex side. After the explosion of the flower he states that the tube can not be straightened to its original position without causing a transverse fracture. No similar elasticity was found in the free filament or in the pistil, but the tendency of the keel to open laterally was noted. Henslow also observed honeybees gathering nectar from alfalfa flowers, but in no instance observed by him was the bee able to trip the flower. He also mentions that he did not see bumblebees visiting the flowers. These observations were made in England.

In the same year Delpino described the structure and mechanism of the alfalfa flower. He apparently considered the explosive force due to the irritability of the staminal tube. Hildebrand¹ criticizes this conclusion and points out that the explosion is due to the tension of the upper filaments in the staminal tube. He agrees, however, that, after tripping, insects are barred from reaching the nectary.

Urban,² in 1873, refers to some of the preceding literature and gives a detailed description of the corolla and of the explosive mechanism. According to his observations, only bees bring about pollination, although butterflies are frequent visitors. In rare cases untripped flowers were found to form pods and seeds. Shortly after the flower has been tripped the opening to the nectary is closed by the drooping of the edges of the standard.

In the same year Müller³ gave an extended description of the alfalfa flower, together with excellent figures, in which the whole mechanism is clearly explained. The elastic tension of the staminal column is mainly in the upper stamens, as can be determined by dividing the upper ones from the lower. The former then show much greater curvature. Müller gives a considerable list of insects, including the honeybee and numerous butterflies, which he had observed sucking nectar from the flowers, but states that he never succeeded in seeing the explosion of the flower actually performed by insects, though he watched for it frequently. He also states that self-pollination in untripped flowers does occur, citing Hildebrand's work as confirmatory. Müller also calls attention to certain imperfections of the mechanism of the flower, namely, that nectar secretion continues to take place after the flower is exploded, thus continuing to attract insects without obtaining any additional benefit, and, second, that bees and butterflies can obtain the nectar by inserting the proboscis on one side of the untripped flower, which under no circumstances results in tripping.

¹ Hildebrand, F. H. G. Federigo Delpino's Beobachtungen über die Bestäubungsvorrichtungen bei den Phanerogamen. Botanische Zeitung, Jahrg. 25, No. 36, p. 283, 1867.

² Urban, I. Prodrömus einer Monographie der Gattung *Medicago* L. Verhandlungen, Botanischer Verein, Provinz Brandenburg, Jahrg. 15, p. 13-16, 1873.

³ Müller, Hermann. Die Befruchtung der Blumen durch Insekten und die gegenseitigen Anpassungen beider. Leipzig, 1873, 478 p., 152 fig.

Henslow¹ in discussing self-fertility in *Medicago sativa* wrote as follows:

This plant, when protected, yielded seeds, as compared with unprotected, in the ratio of 101:77. Hence it is highly self-fertile, though specially modified, in having "irritable" stamens, for cross-fertilization.

This note of Henslow has been cited by later writers, but it is really an erroneous abstract from Darwin's discussion of *Medicago lupulina*. Darwin² writes as follows:

Medicago lupulina (Leguminosæ). On account of the danger of losing the seeds, I was forced to gather the pods before they were quite ripe; 150 flower-heads on plants visited by bees yielded pods weighing 101 grains; while 150 heads on protected plants yielded pods weighing 77 grains. The inequality would probably have been greater if the mature seeds could have been all safely collected and compared.

As Henslow's paper is primarily a review of Darwin's book, it is clear from the two quotations that Henslow erroneously wrote "sativa" in place of "lupulina." This is rendered the more certain as Henslow in his earlier paper on *Medicago sativa* had referred to Darwin's work in a footnote, where the data are properly stated to apply to *Medicago lupulina*.

In 1895 appeared a paper by Burkill,³ who reviews the principal contributions to this subject by previous writers and adds important new observations and experiments. He verifies the conclusions of earlier investigators that the explosive action of the flower depends on the uppermost stamens of the staminal tube. Burkill obtained no pods in a considerable number of flowers covered with nets to prevent insect visits, for which phenomenon he presents an interesting explanation:

Pollen is shed in the bud and lies round the stamens and stigma in a little lens-shaped space made by the carina. . . . No seeds are set in the unexploded flower in spite of the pollen in contact with the stigma. This is explained by the fact that the stigma does not become receptive until rubbed or until its cells are injured in some manner. My proof is, I think, conclusive. Firstly, the stigma appears not to be moist, but when rubbed on glass leaves a sticky mark. Secondly, I have caused flowers to set seed though unexploded, (1) by pinching the stigma through the keel, (2) by perforating the keel and rubbing the stigma with a stiff paint brush, and (3) by cutting off the tip of the keel and rubbing the stigma with a stiff paint brush. An insect visitor exploding the flower will injure the stigmatic papillæ and bring about fertilization.

Burkill gives a list of 31 insects which he observed visiting alfalfa flowers in and near Cambridge, England. In no case did he see a butterfly causing the flower to trip, but on one hot afternoon he

¹ Henslow, George. On the self-fertilization of plants. Transactions, Linnæan Society, London, Botany, s. 2, v. 1, pt. 6, p. 361, 1879.

² Darwin, Charles. The Effects of Cross and Self Fertilization in the Vegetable Kingdom. New York, 1877, p. 368.

³ Burkill, I. H. On the fertilization of some species of *Medicago* L. in England. Proceedings, Cambridge Philosophical Society, v. 8, pt. 3, p. 142-147, 1894.

watched a bumblebee tripping the flowers in great numbers and on two occasions observed honeybees doing the same thing.

In artificially tripped flowers Burkill found that 12 out of 34 tripped set seed; 50 flowers from which the standard had been removed were artificially tripped and none set seed. The impact on the standard, Burkill believes, ruptures the stigma sufficiently to insure fertilization in about one-third of the cases. Burkill's interesting data on the tripping of alfalfa flowers when vertical force is applied to the tip of the keel are quoted in full on page 27 of this paper.

Hunter¹ conducted observations on the relation of the number of seeds per pod in alfalfa as correlated with the proximity of domestic honeybees. He evidently assumes that honeybees are capable of pollinating the flowers, but he does not record any observations of his own on this point. Pods were compared from two fields, one within half a mile of a large apiary, the other 25 miles distant from any domestic bees, none of which were observed in the latter field. Of pods taken half a mile from a large apiary, 87 contained 482 seeds, or 5.58 per pod; 80 pods taken 25 miles distant from any colony of domestic bees produced 268 seeds, or 3.35 per pod.

Kirchner,² after pointing out that the data on the self-fertilization of alfalfa are contradictory, gives results of his own experiments at Hohenheim, Germany. Of exposed clusters of blossoms, 54 on two plants with 432 blossoms produced, August 23, 208 pods, which, though they were not perfectly ripe, showed that they contained 636 well-developed seeds. On the other hand, 21 covered clusters of blossoms on the same plants with 166 blossoms produced only 2 pods with 3 seeds. He concludes that alfalfa flowers are self-sterile, and suggests that Henslow's results were due to some experimental error.

Westgate,³ in 1906, presented a brief review of the work of Henslow, Urban, Burkill, and Kirchner, calling attention to the disagreements in the results of different investigators and pointing out the need of further studies.

Fruwirth⁴ found that inclosed plants occasionally formed a few pods at Vienna, Austria.

Roberts and Freeman⁵ have recorded results of alfalfa pollination experiments at the Kansas Agricultural Experiment Station. Great

¹ Hunter, S. J. Alfalfa, grasshoppers, bees: their relationship. University of Kansas, Department of Entomology; contribution 65, p. 84, 1899.

² Kirchner, O. Über die Wirkung der Selbstbestäubung bei den Papilionaceen. Naturwissenschaftliche Zeitschrift für Land- und Forstwirtschaft, Jahrg. 3, Heft 1, p. 9-10, 1905.

³ Westgate, J. M. A method of breeding a strain of alfalfa from a single individual. American Breeders' Association, Proceedings, v. 2, p. 65-67, 1906.

⁴ Fruwirth, Carl. Die Züchtung der Landwirtschaftlichen Kulturpflanzen. Bd. 3, Berlin, 1906, p. 189.

⁵ Roberts, H. F., and Freeman, G. F. Alfalfa breeding: materials and methods. Kansas Agricultural Experiment Station, Bulletin 151, p. 79-109, 14 fig., 1908.

differences were observed among individual plants as regards seed production. Of seven plants which showed marked differences in this respect, five were classified as "strong" and two as "weak." When these plants were inclosed in screens to exclude pollinating insects the same tendencies remained evident, two of the plants producing pods and seeds in much greater numbers than the others.

In a second series of plants inclosed in screens and self-pollinated by hand the percentage of pods to flowers pollinated varied on different plants from 5.5 per cent to 65.4 per cent, and in one exceptional instance 115 per cent. In this last case some flowers evidently formed pods without hand pollination. A single plant was inclosed in a wire cage to exclude insects. On one half the stems the flowers were self-pollinated by hand and produced 97 pods containing 118 seeds. The other half, not hand pollinated, produced 37 pods containing 59 seeds.

In another experiment the investigators inclosed one half of each of five plants in a screen cage, leaving the other half exposed to natural conditions of pollination. The flowers inclosed in the cage were self-pollinated by hand; those outside the cage were naturally pollinated, but not necessarily cross-pollinated by insects, as assumed. The results they obtained are shown in Table I. A remarkable feature is the extraordinarily large proportion of sterile pods recorded.

TABLE I.—*Results of natural and of artificial pollination of alfalfa, at Manhattan, Kans., by Roberts and Freeman.*

Plant.	Method of pollination.	Weight of stems (grams).	Number of stems.	Number of pods.	Pods producing seeds.		Number of seeds.		
					Number.	Per cent.	Produced.	Average per pod.	Per 10 grams weight of plant.
No. 29.....	Insects....	49.87	11	255	30	11.76	61	2.03	12.2
	Hand.....	35.63	9	272	12	4.41	14	1.17	3.9
No. 38.....	Insects....	103.88	12	327	91	27.82	164	1.80	15.7
	Hand.....	114.00	18	279	164	58.77	236	1.44	20.7
No. 97.....	Insects....	28.50	8	239	65	27.19	67	1.03	23.5
	Hand.....	37.00	20	608	103	16.94	128	1.24	34.6
No. 98.....	Insects....	85.50	11	449	228	50.78	451	1.96	52.7
	Hand.....	64.13	8	779	57	7.30	70	1.22	10.9
No. 109.....	Insects....	14.00	6	198	67	33.83	96	1.43	68.5
	Hand.....	14.00	8	311	180	57.87	239	1.32	170.7
Summary.....	Insects....	281.75	48	1,468	481	32.76	839	1.74	29.7
	Hand.....	264.76	63	2,249	516	22.49	687	1.33	25.9

Brand and Westgate¹ give a brief discussion of the relation of insects to the production of alfalfa seed. These authors assert that "insect visitors are essential to the proper pollination of the alfalfa flower." They state that bumblebees are the most efficient of all insects in tripping the flowers and hence bring about pollination.

¹ Brand, C. J., and Westgate, J. M. Alfalfa in cultivated rows for seed production in semiarid regions. U. S. Department of Agriculture, Bureau of Plant Industry, Circular 24, 23 p., 3 fig., 1909.

Honeybees are not nearly so effective as bumblebees, but should not be underrated in this connection, while bees of the genera *Andrena* and *Megachile* and various butterflies are also valuable agents in pollinating alfalfa flowers.

Results are also given showing the seed production of plants whose flowers were artificially tripped in comparison with untreated plants. At Arlington farm, Virginia, artificial tripping resulted in an increased production of 25.5 per cent, while at Chico, Cal., an increase of 129 per cent of pods was obtained.

Piper,¹ in a report of the American Breeders' Association committee on forage crops relating to the breeding of alfalfa, gives an epitome of the answers of members to various subjects of inquiry, five of which relate to pollination. The answers are diverse, some of them based on experiment and careful observations and others more or less expressions of opinion.

Westgate² records that he observed over 500 visits of honeybees to alfalfa flowers, the flower being tripped in but one case.

Wildermuth³ records with some doubt that he has seen the butterfly of the alfalfa caterpillar (*Eurymus eurytheme*) trip alfalfa flowers. In a personal interview he states that he observed five or six individuals trip the flowers during one season, but has not seen it since, though he has frequently watched the butterflies. This butterfly is very common on alfalfa throughout the Western States.

It will be noted from the brief reviews given that investigators have differed as to their conclusions on several points in connection with the pollination of the alfalfa flower. The most important questions that affect the problem of seed yield left in doubt are the following:

1. To what extent are the flowers self-fertile?
2. Is cross-pollination more effective than self-pollination?
3. Do alfalfa flowers trip automatically?
4. Do untripped flowers form pods and seeds?
5. Is the rupturing of the stigma essential to its becoming receptive?
6. To what extent do honeybees trip alfalfa flowers?

In the investigations reported in this paper will be found abundant data which go far to clear up the discrepancies in previous work.

STRUCTURE OF THE ALFALFA FLOWER.

The structure of the alfalfa flower has been described and illustrated in detail by Hermann Müller and other writers. The most interesting feature is the explosive apparatus which functions to facilitate pollination and under proper conditions to favor cross-pollination. The

¹Piper, C. V. Alfalfa and its improvement by breeding. American Breeders' Association, Report, v. 5, 1908/09, p. 94-115, 1909.

²Westgate, J. M. Methods of breeding alfalfa by selection. American Breeders' Association, Report, v. 5, 1908/09, p. 147, 1909.

³Wildermuth, V. L. The alfalfa caterpillar. U. S. Department of Agriculture, Bureau of Entomology, Circular 133, p. 1, 1911.

essential parts of the mechanism (fig. 1) are the tension of the staminal tube, which is held from contracting by two opposite restraining lateral processes on the inside of the keel. These processes are really

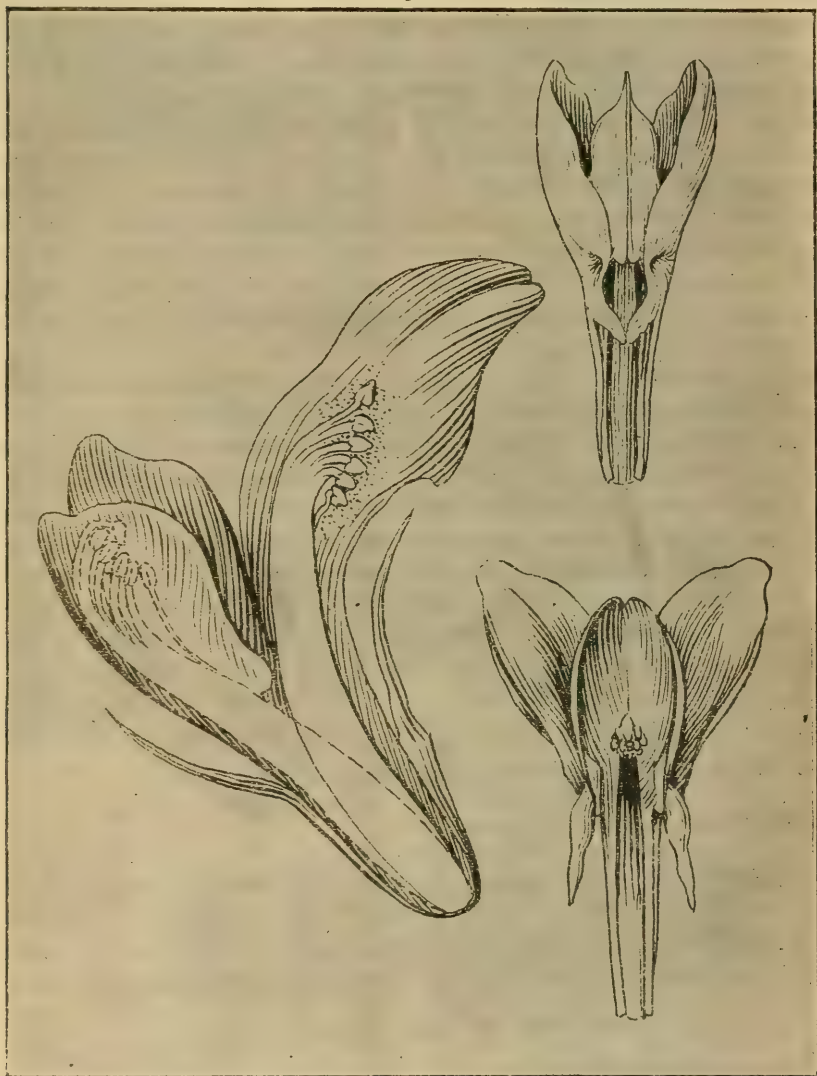


FIG. 1.—Alfalfa flower (much enlarged). The left-hand figure shows an optical section of the flower, indicating the position of the staminal column before and after tripping. The upper right-hand figure gives a view from above of an untripped flower with the calyx and standard removed; the lower right-hand figure, the same after tripping.

invaginations, on the outside occurring as depressions. Each of the wing petals is provided with two fingerlike processes, one extending forward and the other backward. The anterior process of each wing fits into the depression on the same side of the keel, and the two wings

thus serve to strengthen the keel. Contrary to Müller's statement, both of the wings can, by exercising great care, be removed without tripping the flower, thus showing that their function is purely secondary. The posterior processes of the wing meet on top of the staminal column. They can have but little, if any, effect in confining the column in position, as Henslow supposed, for the reason above stated, namely, that their removal is not necessarily followed by explosion. The keel is not purely passive, but its basal tissues are under a lateral tension which tends to pull it open, as Henslow first observed. This tension is restrained by the pressure of the staminal tube against the two internal knobs. If both the apex and the base of the staminal column are severed by a razor, so that pressure is removed from the keel, the latter will open automatically. If the edges of the keel are again brought together, they open as soon as the restraining force is removed. In an uninjured flower a very slight separation of the edges of the keel, and consequently of the restraining knob, will release the tense staminal column. Heavy insects, like bumblebees, may do this by their combined weight and pressure on the tip of the keel, but usually it is accomplished by the insect's proboscis separating ever so slightly the upper posterior edges of the keel. This may be done directly, but more commonly by spreading apart the two posterior processes of the wings and thus indirectly spreading the keel. The terminal part of the keel, notwithstanding the cohesion of the two petals, has little influence to prevent tripping, as, with the inclosed staminal tube and style, it can be cut off with a razor without releasing the explosive mechanism.

As shown by Henslow, and perhaps earlier by Delpino, the elastic tension lies entirely in the coalesced filaments of the nine anthers and not at all in the style. With care the style can be severed at the base without affecting the tripping movements, as Henslow pointed out.

After tripping, the opening to the nectary is almost closed by the upcurved staminal tube, but insects continue to visit tripped flowers until the wilting of the petals makes the closure complete.

The occurrence of this explosive mechanism is not unique in the alfalfa flower, but is found in at least 20 other species of *Medicago* which have been examined in this connection. In yellow or sickle alfalfa the staminal column is relatively much shorter, but the mechanism is the same. It is also very well developed in *Medicago scutellata*, *M. rugosa*, *M. turbinata*, *M. rigidula*, *M. ciliaris*, and *M. echinus*. It is less noticeable in some other annual species, because the staminal column is shorter and not exposed when tripped, as in alfalfa and the species just mentioned. Other genera in which tripping mechanisms occur are *Alysicarpus*, *Trigonella*, *Indigofera*, and *Genista*.

RELATION OF TRIPPING TO THE DEVELOPMENT OF SEED.

In order to obtain more abundant data in regard to the relation of tripping to the production of pods and seeds, the experiment here described was conducted:

On selected plants, approximately two-thirds of the branches were inclosed in fine-meshed mosquito-bar tents to prevent insects from having access to the flowers. Tarlatan was the material used for the netting. The meshes averaged 25 to the linear inch, thus being from one-half to one-third finer meshed than ordinary mosquito bar, which was thought to be too coarse to exclude the smaller insects which might gain access. The remaining stems of each plant were left outside the tent, where the flowers could develop under natural conditions. On both portions of the plant a number of racemes were marked, each with a tag, and numbered. All unopened flower buds and all wilted or tripped flowers were cut off from each of these racemes, leaving only the fresh, open, and untripped flowers. The flowers on approximately one-half of the marked racemes inside the netting were artificially tripped. This was done usually by means of a slender alfalfa stem or grass stem, pushed down between the keel and the standard. On some of the plants used in this experiment, a separate stem was used for each flower, so as to exclude pollen from other flowers, while on other plants the same stem was used to trip several flowers on the same plant. The flowers were fertilized in all cases, therefore, with pollen from the same flower or with pollen of other flowers on the same plant. The flowers on the remaining racemes inside of the netting tent were allowed to develop without being tripped through the visit of insects or by any artificial agency.

This experiment was carried out at Pullman, Wash., in 1908, 1909, and 1910; at Chico, Cal., in 1908 and 1909; at Arlington farm, Virginia, in 1908; at Chinook and Havre, Mont., in 1909; and at New London, Ohio, in 1912. The summarized results are shown in Table II.

TABLE II.—*Pods and seeds produced by alfalfa flowers on the same plants, free and protected from insects.*

A.—OUTSIDE NETTING: FLOWERS DEVELOPED UNDER NATURAL CONDITIONS.

Year.	Place.	Number of plants.	Total number of flowers.	Number of pods.	Total number of seeds.	Flowers bearing pods.	Average number of seeds per pod.
						<i>Per cent.</i>	
1908.....	Pullman.....	7	633	155	426	24.47	2.74
	Chico.....	15	3,474	321	681	9.24	2.12
	Arlington.....	1	80	35	31	43.75	.88
1909.....	Pullman.....	15	1,468	480	1,730	32.69	3.60
	Chinook.....	10	944	143	320	15.14	2.23
	Havre.....	9	366	51		13.93	.....
	Chico.....	8	1,589	228		14.34	.....
1910.....	Pullman.....	6	228	30	38	13.15	1.26
1912.....	New London.....	6	157	56	105	35.66	1.80
Total.....		77	8,939	1,499	3,331	.....	.....
Average.....						16.76	2.22

TABLE II.—*Pods and seeds produced by alfalfa flowers on the same plants, free and protected from insects—Continued.*

B.—INSIDE NETTING: FLOWERS NOT TRIPPED EITHER ARTIFICIALLY OR BY INSECTS.

Year.	Place.	Number of plants.	Total number of flowers.	Number of pods.	Total number of seeds.	Flowers bearing pods.	Average number of seeds per pod.
						<i>Per cent.</i>	
1908.....	Pullman.....	7	651	25	29	3.84	1.16
	Chico.....	15	4,116	157	230	3.81	1.46
	Arlington.....	1	37				
1909.....	Pullman.....	15	1,500	131	357	8.73	2.72
	Chinook.....	10	1,186	138	282	11.63	2.04
	Havre.....	9	535	30		5.60	
	Chico.....	8	832	15		1.80	
1910.....	Pullman.....	6	314	12	22	3.82	1.83
1912.....	New London.....	6	169	11	11	6.50	1.00
Total.....		77	9,340	519	931		
Average.....						5.55	1.78

C.—INSIDE NETTING: FLOWERS ARTIFICIALLY TRIPPED.

1908.....	Pullman.....	7	576	148	205	25.67	1.38
	Chico.....	15	4,229	1,086	1,908	25.67	1.75
	Arlington.....	1	22	7	9	31.81	1.30
1909.....	Pullman.....	15	1,379	599	1,783	43.43	2.97
	Chinook.....	10	830	370	681	44.57	1.84
	Havre.....	9	337	104		30.86	
	Chico.....	8	1,250	345		27.60	
1910.....	Pullman.....	6	296	75	103	25.33	1.37
1912.....	New London.....	6	155	50	91	32.25	1.80
Total.....		77	9,074	2,784	4,780		
Average.....						30.68	1.72

In Table II there are no data to indicate what percentage of flowers actually tripped by insects or other natural agencies form pods. Data on this point were secured by observations at Pullman, Wash., in 1908. Flowers which had been tripped naturally were marked by putting a drop of insoluble drawing ink on the calyx of each. The racemes were then inclosed in netting to prevent other insect visits. The results are shown in Table III.

TABLE III.—*Pods and seeds produced from alfalfa flowers tripped under natural conditions.*

Raceme.	Number of flowers.			Number of pods developed from—		Total number of seeds developed.	
	In raceme.	Tripped.	Not tripped when inclosed.	Tripped flowers.	Flowers not tripped when inclosed.	From tripped flowers.	From flowers not tripped when inclosed.
No. 1.....	11	4	7	2		2	
No. 2.....	11	8	3	5		33	
No. 3.....	16	11	5	8		55	
No. 4.....	8	6	2	3		2	
No. 5.....	17	11	6	7	1	11	1
No. 6.....	10	5	5	4		14	
No. 7.....	18	10	8	2		2	
No. 8.....	9			8		33	
No. 9.....	11	6	5	5		11	
No. 10.....	13	8	5	4		3	
No. 11.....	15	8	7	6		25	
No. 12.....	11	7	4		2		2
Total.....	150	93	57	54	3	191	3

Tripped flowers bearing pods.....	per cent..	58.06
Flowers not tripped when inclosed bearing pods.....	do....	5.26
Average number of seeds per pod from tripped flowers.....		3.53
Average number of seeds per pod from flowers not tripped when inclosed.....		1.00

The abundant data presented in Table II permit the following conclusions:

(1) Flowers not tripped either artificially or by insects may produce pods. The percentage of pods to flowers under these conditions varies from 11.63 to 0, the average for 77 plants being 5.55.

(2) Flowers artificially tripped produce pods in percentages ranging from 25.33 to 44.57, the average for 9,074 flowers on 77 plants being 30.68.

(3) Under natural conditions the percentage of flowers setting pods varies from 9.24 to 43.75. The average percentage of pods from 8,939 flowers on 77 plants is 16.76.

(4) The number of seeds per pod in artificially tripped flowers is usually less than in naturally fertilized flowers, the average number of seeds per pod for 77 plants being 1.72 in the former case and 2.22 in the latter. In caged plants not tripped either artificially or by insects the pods averaged 1.78 seeds each. The larger number of seeds per pod in the exposed portions of the plants is perhaps due to cross-pollination.

RELATION OF INSECTS TO TRIPPING.

To obtain data on the efficiency of insects in tripping alfalfa flowers, observations have been made at Pullman, Wash.; Chinook and Havre, Mont.; Chico, Cal.; and at Arlington farm, Virginia. No attempt was made to secure a list of visiting species, the object being rather to ascertain the relation, if any, of insect visitors to seed formation.

BEES.

Among the commonest insects which visit alfalfa flowers are honey-gathering bees. The data from detailed observations made at Pullman, Wash., and Chinook and Havre, Mont., are shown in Table IV.

TABLE IV.—*Alfalfa flowers tripped by different honey-gathering bees.*

Year.	Species.	Where observed.	Total number of flowers visited.	Flowers tripped.	
				Number.	Per cent.
1909....	<i>Apis mellifica</i>	Pullman, Wash.....	318	1	0.31
1910....	do.....	do.....	189	3	1.58
1909....	do.....	Chinook, Mont.....	126	6	4.76
1909....	<i>Bombus</i> spp. ¹	Havre, Mont.....	268	79	29.47
1909....	<i>Megachile latimanus</i>	Pullman, Wash.....	52	47	90.38
1909....	do.....	Chinook, Mont.....	45	42	93.33

¹ Four species of *Bombus* were found tripping flowers at Havre, viz, *B. auricomus* Robertson, *B. separatus* Cresson, *B. bifarius* Cresson, *B. borealis* Kirby.

It will be noted that the leaf-cutting bee (*Megachile latimanus* Say) is by far the most efficient, tripping about nine flowers out of every ten visited. Bumblebees are decidedly inferior to *Megachile*, tripping

only about 30 per cent of the flowers visited. No attempt was made to secure records of different species of *Bombus*, but there is certainly considerable difference in their ability to trip the flowers. The larger bumblebees are clumsy insects and at Chico have been observed to trip with their feet flowers other than the one in which the proboscis was inserted. Honeybees trip but few alfalfa flowers, as previously noted by other observers.

In 1907 a single individual of *Megachile latimanus* was observed to trip 4 flowers in 30 seconds at Pullman, Wash.; another tripped 12 flowers in 70 seconds, and a third tripped 20 flowers in 2 minutes and 15 seconds. These three bees tripped flowers at the rate of 9.2 flowers per minute, or 552 flowers per hour.

The process of tripping is thus described by Evans:

When *Megachile latimanus* visits an alfalfa flower, it grasps the wings or the keel from below, braces its head up against the standard, and in this way forces the wing and keel petals apart from the standard, so that it can push its head down and reach the honey. As a result, the flower is usually tripped. When this occurs, the pollen is thrown in a miniature cloud that is sometimes visible to the eye. There is abundant opportunity for the pollen to lodge upon the head and other parts of the bee, where portions of it can easily come in contact with the stigma of the next flower that is tripped. Occasionally the proboscis of a bee is caught by the pistil, which after the flower is tripped presses up quite closely to the standard. When thus caught, the bee braces up on all six legs and after one or two vigorous shakes releases itself. Such an accident does not result in any injury to the bee, but merely occasions a short delay. The insect then rubs its proboscis with the two front feet and flies off to gather honey from other flowers.

Honeybees were also carefully observed by McKee at Chico, Cal., in 1909. But few flowers were tripped by these insects, though repeated visits seemed to increase the ease of tripping. Thus, one flower tripped after four visits by honeybees; another, after seven visits. In other cases, however, the flowers did not trip even after seven visits by honeybees.

Short-tongued bees of the genus *Andrena* have also been observed tripping alfalfa flowers both at Pullman, Wash., and at Arlington farm, Virginia.

BUTTERFLIES.

Various species of butterflies are among the common insect visitors to alfalfa flowers, the most abundant at Pullman, Wash., and Chinook, Mont., being species of *Pieris* and *Eurymus*. Several species of butterflies were carefully observed at the two places above mentioned as well as at Chico, Cal., and at Arlington farm, Virginia, but in no case was an individual seen to trip a flower. In all cases the butterfly inserts its proboscis at one side of the flower. Our observations on these insects agree fully with those of Urban.

MOTHS AND OTHER NIGHT-FLYING INSECTS.

Owing to the fact that tripped flowers are sometimes abundant while day-flying insect visitors are scarce, it was suspected that night-flying insects might be a factor. To secure information on this point two series of experiments were undertaken.

One of these experiments was conducted at Pullman, Wash., in 1909. Seven alfalfa plants were inclosed in fine-meshed mosquito netting. Five of the plants were left under the netting during the entire time of the experiment in order to find out what proportion of the flowers become tripped when insects were entirely excluded. Two of the plants were kept inclosed in netting during the daytime, but were uncovered during the night. The results obtained are given in Table V.

TABLE V.—*Alfalfa flowers tripped by night-flying insects at Pullman, Wash., 1909.*

On plants inside of netting.			On same plants outside of netting; open to insects.	
Plant.	Flowers tripped.	Flowers bearing pods.	Plant.	Flowers bearing pods.
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>
No. 11.....	* 0	* 1.16	No. 11.....	37.31
No. 12.....	* 0	* 0	No. 12.....	16.12
No. 14.....	* 3.92	* 8.57	No. 14.....	56.60
No. 15.....	* 3.03	* 2.59	No. 15.....	20.51
No. 17.....	* 0	* 1.36	No. 7.....	35.38
No. 7.....	† 4.63	† 5.78	No. 10.....	30.35
No. 10.....	† 4.60	† 2.51		

* Inclosed in netting during entire experiment. † Inclosed in daytime; open for night-flying insects.

A similar experiment was conducted at Chico, Cal. On May 31, 1909, 400 alfalfa flowers on several different plants were marked and observed until June 2. Table VI shows how many flowers were tripped during the day or night.

TABLE VI.—*Alfalfa flowers tripped during different periods of the day and night at Chico, Cal., 1909.*

Period covered.		Number of flowers tripped.	Period covered.		Number of flowers tripped.
From—	To—		From—	To—	
4 p. m., May 31.....	7.30 p. m., May 31.	22	11 a. m., June 1....	2 p. m., June 1....	16
7.30 p. m., May 31....	5.30 a. m., June 1..	0	2 p. m., June 1.....	4 p. m., June 1....	18
5.30 a. m., June 1....	10 a. m., June 1....	23	4 p. m., June 1.....	7.30 p. m., June 1..	18
10 a. m., June 1.....	11 a. m., June 1....	11	7.30 p. m., June 1....	6 a. m., June 2.....	0

From the evidence presented in the two preceding tables, as well as from the results of observations made at other times and places, it is clear that night-flying insects are at most a small factor in tripping alfalfa flowers.

MISCELLANEOUS INSECTS.

A number of species of small insects visit alfalfa flowers, not for the purpose of getting honey, but to feed upon the pollen and the cellular tissue of the flower. The most common insects of this kind are the thrips. These insects are found in all parts of the United States, and have frequently been abundant in the alfalfa flowers at Arlington farm, Virginia; Chico, Cal.; Pullman, Wash.; and at Chinook and Havre, Mont. At Pullman 1,119 thrips were found on 16 racemes of alfalfa flowers, or an average of 69.9 thrips on the flowers of each raceme. At Havre 48 thrips were found on 13 racemes. These minute insects do not trip the alfalfa flowers.

In conducting the various experiments described in this paper, it has been observed that even when the thrips are present in very large numbers the flowers very rarely develop into pods and seed unless tripped. On the other hand, when the flowers are tripped, a large proportion usually produce pods and seeds, even though the thrips are very abundant. The evidence at hand indicates that the thrips are neither appreciably beneficial nor injurious in their influence upon the development of alfalfa seed.

Another insect commonly found on alfalfa flowers is the tarnished plant bug (*Lygus pratensis*). Blister beetles (*Epicauta puncticollis* Mannerheim) are found on alfalfa in abundance at Pullman, Wash., feeding on the more tender portions, especially the stamens and style. At Brookings, S. Dak., occurs the related *Macrobasis unicolor* Kirby. This beetle, according to R. A. Oakley, does considerable damage to the flowers, but incidentally trips many.

EFFECTS ON SEED SETTING OF VISITS OF INSECTS WITHOUT TRIPPING FLOWERS.

To determine whether or not the visiting of flowers by insects without actual tripping aids in seed setting, observations were made at Chico, Cal., as shown in Table VII. The plants designated as A, B, and C were in full bloom at the time of beginning the experiment, and up to that time were not protected in any way. After counting and tagging the old and young flowers to be observed, the plants were screened with tarlatan netting, with the exception of a portion of plant B, which was left to develop under natural conditions.

The flowers designated as old flowers were the oldest on the plant not tripped at the time the experiment was started, and many of them probably had been visited one or more times by bees or other insects without tripping. That insects had visited the older flowers is merely assumption, but as many bees and other insects were working the alfalfa flowers on the days immediately preceding the starting of the experiment, this seems probable. The flowers designated as young flowers were not yet in bloom when they were screened.

TABLE VII.—*Effects on seed setting of visits of insects without tripping the alfalfa flower at Chico, Cal., 1909.*

Description of flowers.	Plant.	Number of flowers.	Pods set.	
			Number.	Per cent.
Young flowers untripped and protected from insect visitors....	A	109	3	2.74
	B	34	0	0
	C	40	1	2.5
Old flowers untripped and protected from further insect visitors....	A	311	5	1.6
	B	47	0	0
	C	33	0	0
Young flowers developed under natural conditions.....	B	52	31	59.61
Old flowers developed under natural conditions.....	B	70	18	25.71

These results indicate that a small percentage of flowers set pods without insect visitors and that insect visitors that do not trip the flowers have no effect.

EFFECT OF POLLEN FROM DIFFERENT SOURCES.

To determine the relative effects of self-pollination and cross-pollination, a series of experiments was conducted at Pullman, Wash., Chico, Cal., and New London, Ohio. Using the same female parent, pollen was applied to the stigma (*a*) from the same flower, (*b*) from another flower on the same plant, and (*c*) from another plant of the same variety. The results are presented in Table VIII.

TABLE VIII.—*Pods and seeds produced by alfalfa flowers when fertilized by pollen from different sources.*

A.—WHEN POLLINATED FROM THE SAME FLOWER.

Locality.	Year.	Plant No.	Number of flowers.	Number of pods.	Flowers bearing pods.	Number of seeds.	
						Total.	Average per pod.
Chico, Cal.....	1909	3399	65	17	<i>Per cent.</i> 26.0		
Do.....	1909	5099	95	34	35.7		
Pullman, Wash.....	1910	1	43	9	20.9	11	1.2
Do.....	1910	3	29	2	6.9	2	1.0
Do.....	1910	5	61	42	68.8	55	1.3
Do.....	1910	7	50	19	38.0	34	1.8
New London, Ohio.....	1912	1	33	1	3.0	0	0
Do.....	1912	2	26	16	61.5	24	1.5
Do.....	1912	3	13	0	0	0	0
Do.....	1912	4	27	13	48.1	26	2.0
Do.....	1912	5	32	12	37.5	6	.5
Do.....	1912	6	39	0	0	0	0
Total.....			513	165		158	
Average.....					32.1		1.4

TABLE VIII.—*Pods and seeds produced by alfalfa flowers when fertilized by pollen from different sources—Continued.*

B.—WHEN POLLINATED FROM DIFFERENT FLOWERS ON THE SAME PLANT.

Locality.	Year.	Plant No.	Number of flowers.	Number of pods.	Flowers bearing pods.	Number of seeds.	
						Total.	Average per pod.
					<i>Per cent.</i>		
Chico, Cal.....	1909	3399	26	4	15.4		
Do.....	1909	5099	28	12	42.9		
Pullman, Wash.....	1910	1	34	9	26.5	18	2.0
Do.....	1910	3	69	9	13.0	18	2.0
Do.....	1910	5	66	33	50.0	90	2.7
Do.....	1910	7	59	17	28.8	21	1.2
New London, Ohio.....	1912	1	31	1	3.2	0	0
Do.....	1912	2	23	19	82.6	63	3.3
Do.....	1912	3	15	6	40.0	8	1.3
Do.....	1912	4	26	14	53.8	13	.9
Do.....	1912	5	28	8	28.5	7	.8
Do.....	1912	6	32	2	6.3	0	0
Total.....			437	134		238	
Average.....					30.6		2.02

C.—WHEN POLLINATED FROM FLOWERS OF DIFFERENT PLANTS OF THE SAME VARIETY.

Chico, Cal.....	1909	3399	44	31	70.5		
Do.....	1909	5099	43	15	34.9		
Pullman, Wash.....	1910	1	38	18	47.4	39	2.2
Do.....	1910	3	54	21	38.8	113	5.4
Do.....	1910	5	48	24	50.0	49	2.0
Do.....	1910	7	51	20	39.6	58	2.9
New London, Ohio.....	1912	1	34	10	29.4	13	1.3
Do.....	1912	2	25	18	72.0	27	1.5
Do.....	1912	3	19	9	47.3	14	1.5
Do.....	1912	4	20	16	80.0	47	2.9
Do.....	1912	5	35	14	40.0	15	1.1
Do.....	1912	6	35	10	28.5	7	.7
Total.....			446	206		382	
Average.....					46.1		2.38

In the first and second sections of Table VIII the most striking fact is the wide variation of the individual plants in their ability to form seed when the flower is self-pollinated or pollinated from another flower of the same plant. There is clearly a great difference between individuals in this respect. In the matter of averages, 513 self-pollinated flowers produced 165 pods, or 32.1 per cent, while 437 flowers, each pollinated from another flower on the same plant, produced 134 pods, or 30.6 per cent. On the same 12 plants, 446 flowers, each cross-pollinated from another plant of the same variety, produced 206 pods, or 46.1 per cent.

From 114 pods of the self-pollinated flowers 158 seeds were produced, an average of 1.4 seeds per pod; 118 pods from the flowers pollinated from another flower on the same plant contained 238 seeds, an average of 2.02 seeds per pod; while 160 pods from the cross-pollinated flowers contained 382 seeds, or 2.38 seeds per pod.

It would appear, therefore, that cross-pollination is more potent than self-pollination, while pollination from another flower on the

same plant gives practically the same results as self-pollination. As the same 12 female parent plants were used in all the experiments, the factor of individual variation is eliminated.

At Chico, Cal., in 1909, flowers on different branches of two selected alfalfa plants were pollinated, (a) from the same flower, (b) from a different flower on the same plant, (c) from a separate plant of the same variety, and (d) from a different variety. The female parent in one case was a plant of Peruvian alfalfa, S. P. I. No. 3399; in another, ordinary alfalfa, F. C. I. No. 5099; and in the third, Turkestan alfalfa, S. P. I. No. 18751. The results at Chico and also of similar experiments conducted at Arlington farm in 1908 and 1909 are given in Table IX.

TABLE IX.—*Results of the pollination of alfalfa flowers from different parents.*

CHICO, CAL., 1909.

Female parent.	Male parent.	Number of flow-ers.	Number of pods.	Flowers bearing pods.	Number of seeds.	
					Total.	Average per pod.
				<i>Per cent.</i>		
3399.....	Same flower.....	65	17	26.0	.....	.....
3399.....	Another flower on same plant.....	26	4	15.4	.....	.....
3399.....	Another plant of same variety.....	44	31	70.5	.....	.....
3399.....	19822, Turkey.....	70	48	68.5	.....	.....
3399.....	12694, Provence.....	76	46	60.5	.....	.....
3399.....	do.....	16	8	50.0	.....	.....
3399.....	18823, Arabia.....	38	28	73.7	.....	.....
3399.....	991, Turkestan.....	47	27	57.5	.....	.....
3399.....	18827, Utah.....	24	11	45.8	.....	.....
5099.....	Same flower.....	95	34	35.7	.....	.....
5099.....	Another flower on same plant.....	28	12	42.9	.....	.....
5099.....	Another plant of same variety.....	43	15	34.9	.....	.....
5099.....	Grimm.....	68	44	64.7	.....	.....
18751.....	Same flower.....	112	5	4.5	.....	.....
18751.....	Another plant of same variety.....	50	23	46.0	.....	.....
18751.....	12694, Provence.....	16	8	50.0	.....	.....

ARLINGTON FARM, VIRGINIA.

F. C. I. 1, M. sativa.....	Same flower.....	125	62	49.6	108	1.7
Do.....	F. C. I. 28, M. sativa (Kan.).....	14	9	64.3	39	4.3
Do.....	F. C. I. 34, Grimm.....	16	15	93.8	50	3.3
Do.....	F. C. I. 2072, M. falcata.....	5	3	60.00	17	5.6
Do.....	S. P. I. 20571, sand lucerne.....	38	27	71.00	126	4.7
Do.....	F. C. I. 152, Kansas variegated.....	8	6	75.00	31	5.1
Do.....	S. P. I. 19534, M. falcata.....	4	4	100.00	16	4.0
F. C. I. 18, M. sativa.....	Same flower.....	267	172	64.4	354	2.0
Do.....	F. C. I. 2072, M. falcata.....	73	51	69.9	259	5.0

The results indicate that cross-pollination is usually much more efficient than self-pollination, whether the latter is by the same flower or by another flower of the same plant. The efficiency of cross-pollination is about the same, regardless of whether the pollen-producing parent is the same or a different variety.

RELATION OF THE NUMBER OF FLOWERS PER RACEME TO THE NUMBER OF PODS FORMED.

In Table III there is some slight evidence to indicate that racemes with many flowers produce proportionately fewer pods than racemes with few flowers. This matter was further investigated by McKee at Chico, Cal., in 1909, and his results are shown in Table X. According to these results it would appear that few-flowered racemes produce proportionately twice as many pods as many-flowered racemes. While this factor is evidently one to be taken into consideration, it could hardly modify materially the results shown in Table II, owing to the very large number of flowers counted in these experiments.

These data are the combined readings from 15 different plants. Exactly analogous conclusions are shown, however, by tabulating the results of each individual plant.

TABLE X.—*Effect of the number of alfalfa flowers per raceme on the percentage of pods set.*

Number of flowers per raceme.	Number of racemes.	Number of flowers.	Number of pods.	Number of pods per raceme.	Number of seeds.		Flowers setting pods.
					Total.	Average per pod.	
2 to 6.....	153	707	317	2.07	553	1.7	<i>Per cent.</i> 44.8
7 to 11.....	138	1,212	464	3.36	806	1.7	38.2
12 to 16.....	50	669	205	4.1	401	1.9	30.6
17 to 26.....	17	344	68	4.0	96	1.4	19.7

AUTOMATIC TRIPPING.

The term "automatic tripping" is used when an alfalfa flower becomes tripped without the aid of insects or any other external body. This phenomenon was first actually observed at Chinook, Mont., in 1909, but was suspected from observations of the previous season at the same place. In 1909 two of the plants inclosed in netting produced pods on racemes from which insects had been excluded. To obtain further facts in regard to the process, all wilted and all unopened flowers were removed from a number of the racemes under the netting, leaving only opened, untripped flowers, which were closely observed during the following days. In the course of a day or two several of the flowers had become tripped. On one of these two plants the keel petals were partially separating in some of the flowers. While these flowers were being examined one flower was seen in the process of tripping. The pistil and stamens snapped up vigorously against the standard, scattering the pollen around. No object had come in contact with any portion of the flower.

The calyx of each tripped flower was marked with carbon ink as soon as it was detected. Those which did not trip were watched until the corolla had wilted or the flower had fallen. The number of

flowers that were tripped and the pods that developed from tripped and untripped flowers are shown in Table XI.

TABLE XI.—Pods and seeds from automatically tripped alfalfa flowers at Chinook, Mont., 1909.

Plant.	Raceme No.	Number of flowers.		Flowers tripped.	Number of pods.			Flowers bearing pods.
		Total.	Tripped.		Total.	From tripped flowers.	From untripped flowers.	
				<i>Per cent.</i>				<i>Per cent.</i>
No. 3.....	34	12	9	75.00	7	7	0	58.33
No. 3.....	35	11	3	27.27	3	3	0	27.27
No. 3.....	36	7	2	28.57	0	0	0	0
No. 3.....	37	11	7	63.63	5	5	0	45.45
No. 3.....	38	10	9	90.00	5	5	0	50.00
No. 3.....	39	6	3	50.00	1	1	0	16.66
Total.....		57	33		21	21	0	
Average.....				57.88				36.84
No. 8.....	30	14	5	35.71	3	3	0	21.42
No. 8.....	31	6	2	33.33	0	0	0	0
No. 8.....	32	20	14	70.00	8	8	0	40.00
No. 8.....	33	11	2	18.18	0	0	0	0
No. 8.....	34	13	13	100.00	5	5	0	38.46
Total.....		64	36		16	16	0	
Average.....				56.25				25.00

Flowers tripped on plants 3 and 8.....per cent.. 57.02

Flowers producing seed on plants 3 and 8.....do..... 30.57

Tripped flowers producing seed on plants 3 and 8.....do..... 53.62

Untripped flowers producing seeds on plants 3 and 8.....do..... 0

At Arlington farm, Virginia, in 1909, an entire alfalfa plant was inclosed in a screen of tarlatan about the time the first flowers came into bloom. Ten days or two weeks later the plant was observed to be in full bloom. When the screen was removed it was noticed that the flowers seemed larger than those on plants that had not been screened. Seventeen racemes were tagged to show the number of flowers on each, all unopened flowers being removed. The screen had been removed only two or three minutes when a snapping or clicking sound was heard. On close observation it was found that some of the flowers had become tripped. The sound of the column striking the standard was quite distinct, but even with very close watching no single flower was actually seen in the act of tripping. No insects visited the flowers of this plant, and the only way in which the flowers could be tripped would be automatic. The day was clear, very warm, and with no breeze stirring. The screen was removed about 11 o'clock in the morning and for not more than 15 minutes. No actual count of the flowers tripped in the manner just described was made. At first the flowers did not trip very fast, but as the plant remained longer in the sunshine the trippings became more frequent. At times three or four would be heard almost simultaneously. The

flowers that tripped first were on the outside of the plant. The screen was replaced, so that insects had no access to the flowers, nor was the screen again removed until the seed was mature.

It was estimated that more than one-half of the flowers counted on each raceme thus became self-tripped before the screen was replaced. None were artificially tripped, as extreme care was taken. The results are presented in Table XII.

No flowers already tripped were noticed when the screen was first removed. Apparently the tripping was induced when the screen was removed by the increased transpiration from the turgid flowers. Certainly no insect agency was involved. The total number of pods produced was 23.7 per cent of the total number of flowers counted and tagged.

TABLE XII.—*Results obtained with a single alfalfa plant screened from insects and exposed for 15 minutes on a bright, warm day when in full bloom, thus bringing about the automatic tripping of its flowers.*

Raceme.	Number of flowers.	Number of pods.	Flowers bearing pods.	Number of seeds.	
				Total.	Average per pod.
			<i>Per cent.</i>		
No. 1.....	26	10	38.4	13	1.3
No. 2.....	16	3	18.7	6	2.0
No. 3.....	12	3	25.0	7	2.3
No. 4.....	17	8	47.0	10	1.2
No. 5.....	20	5	25.0	14	2.8
No. 6.....	18	4	22.2	8	2.0
No. 7.....	12	1	8.3	3	3.0
No. 8.....	22	3	13.6	6	2.0
No. 9.....	14	2	14.2	4	2.0
No. 10.....	14	1	7.1	2	2.0
No. 11.....	16	2	12.5	4	2.0
No. 12.....	18	2	11.1	5	2.5
No. 13.....	17	6	35.2	12	2.0
No. 14.....	17	4	23.5	10	2.5
No. 15.....	24	5	20.8	10	2.0
No. 16.....	12	4	33.3	7	1.7
No. 17.....	20	7	35.0	12	1.7
Total.....	235	70		133	
Average.....			23.7		1.9

In 1910 an experiment was conducted at Pullman, Wash., for the purpose of determining what proportion of flowers became self-tripped. Accordingly, nine alfalfa plants, which were producing more pods and seeds than most of the alfalfa plants in the experimental plats, were inclosed in netting tents and were closely observed for several days.

The tents in which the plants were inclosed were carefully covered with fine-mesh mosquito bar, so that no openings were left for honey-gathering insects to gain access to the flowers. The tents were made large enough and pains were taken so that no flowers which were being watched were in such a position that they could brush against the sides or top of the tent.

After the flowers from which insects were to be excluded had been inclosed in the netting tents, they were examined every day or every second day until all of the flowers had become entirely wilted. Whenever any flower was found tripped, the calyx was marked with a mixture of carbon black and water in order that the pod which might develop from the tripped flower could be distinguished from any pod that might develop from a flower that had not been observed to be tripped. The unmarked flowers were observed until they wilted, so it is certain that none of them became tripped.

Table XIII shows the number of flowers that became tripped and also the number of pods and seeds that developed from tripped and untripped flowers.

TABLE XIII.—*Pods and seeds from self-tripped alfalfa flowers at Pullman, Wash., 1910*

Plant.	Number of flowers.			Number of pods from marked flowers.	Number of mature seeds from marked pods.	Number of pods from flowers not marked.	Mature seeds from pods not marked.
	Total.	Tripped and marked.	Not tripped and not marked.				
No. 8.....	128	9	119	1	0	0	0
No. 9.....	104	17	87	12	18	4	4
No. 10.....	59	2	57	1	0	1	0
No. 11.....	100	15	85	4	3	0	0
No. 12.....	62	4	58	0	0	0	0
No. 13.....	91	1	90	1	1	0	0
No. 18.....	79	3	76	2	4	0	0
No. 19.....	71	8	63	0	0	0	0
No. 20.....	81	1	80	0	0	0	0
Total.....	775	60	715	21	26	5	4

Flowers tripped.....per cent..	7.74
Tripped flowers producing pods.....do....	35.00
Flowers not tripped producing pods.....do....	.69
Average number of mature seeds per pod from tripped flowers.....	1.23
Average number of mature seeds per pod which developed from flowers not observed to be tripped.....	.80

Table XIII shows that 7.7 per cent of the flowers observed on the nine plants became tripped. In several of the flowers the keel was observed gradually to open, and later the flowers were found to be tripped. As the tents were made so that honey-gathering insects did not have access to the flowers and as care was taken to prevent any other object from coming in contact with the flowers, it seems clear that the tripping which occurred was automatic.

Five of the 775 flowers observed produced pods, when no evidence that these flowers had been tripped could be found. It is possible that three of these flowers may have become tripped without being observed or that the carbon which was placed on the calyx may have been removed. However, two flowers were found in which the pod was developing and the tip of the young pod was protruding through

the tip of the keel while the flower remained untripped. This proves that a pod may develop from a flower without the flower having been tripped. The further evidence obtained in this investigation, however, indicates that it is only in rare instances that untripped alfalfa flowers produce seed.

In some seasons the alfalfa plants in the fields about Chinook, Mont., produce seed in abundance, though honey-gathering insects are present in only very small numbers. In other seasons most of the flowers fall off the plants without producing pods and seed, and only light seed crops are harvested. On August 22, 1910, it was found that practically all flowers that had been open for more than a few hours had been tripped and that during a period of 10 days or 2 weeks prior to this time a very large proportion of the flowers had developed into pods. A typical raceme was found to have on it 20 flowers which had been opened. Of this number 15 had become tripped. The 5 flowers not tripped were newly opened, all being located near the top of the raceme. For several days the weather had been bright and warm, though not excessively hot. On this date flowers just beginning to open were inclosed in netting tents and were watched in order to determine what was causing the flowers to become tripped. At this time, however, the weather became much colder, a heavy frost occurring on the night of August 24. After the weather became colder comparatively few flowers were tripped or produced pods. Of a total number of 390 marked flowers inside netting tents, only 1 became tripped; of 333 marked flowers on plants not inclosed in netting, only 3 became tripped. Practically all of the flowers that opened after August 22 fell off the plants without producing pods. Since honey-gathering insects were comparatively rare in the alfalfa fields during the warm weather prior to August 22, it seems evident that a large proportion of the flowers were becoming automatically tripped and that when the weather became colder conditions were no longer favorable for the flowers to become tripped and produce seed.

From the evidence presented, there can be no question that automatic tripping does occur in alfalfa flowers. It also indicates that in rare cases pods form without the flower becoming tripped.

The evidence also shows that atmospheric or climatic conditions greatly affect automatic tripping, so that it is not improbable that this factor alone accounts for a great variation in seed production during different seasons at the same place.

In 1913 it was found at Arlington farm that alfalfa flowers could readily be tripped by focusing sunlight upon them with a burning glass. The tripping takes place without any evident wilting.

At Brookings, S. Dak., in 1913, R. A. Oakley observed that when the flowers in the shade near the ground were carefully raised into

the hot sunshine automatic tripping took place quickly and could easily be observed. These observations remove any possible doubt as to the movement being automatic. It will take place, however, only when the sun's heat is intense. It now seems clear that automatic tripping is induced mainly by hot sunshine, though it is not proved that flowers continually in the sunshine will be tripped to the same extent as those alternately in the shade and exposed.

POLLINATION IN RELATION TO THE RUPTURE OF THE STIGMATIC CELLS.

Burkill's conclusion that the stigma is not susceptible of pollination until the stigmatic cells have been ruptured has already been mentioned. To test this matter further, the following investigations were conducted by J. M. Westgate in the greenhouse at Washington, D. C., by W. J. Morse at Arlington farm, Virginia, and by M. W. Evans at Pullman, Wash. Two methods were used. In the first, the standard was removed and the flower then tripped. The results of the experiment with this method at the three places mentioned are shown in Table XIV.

TABLE XIV.—*The setting of alfalfa pods by flowers tripped after removing the standard.*

Observer.	Place.	Year.	Number of plants.	Number of flowers tripped.	Number of pods formed.	Flowers bearing pods.	Number of seeds.	
							Total.	Average per pod.
Westgate.....	Washington, D. C.	1908	18	468	74	<i>Per cent.</i> 15.8		
Morse.....	Arlington farm....	1908	5	123	28	22.8	37	1.3
Do.....	do.....	1909	5	23	10	43.4	16	1.6
Evans.....	Pullman, Wash....	1909		113	14	12.4		

These results show clearly that the mechanical effect of the stigma striking the standard is not necessary to insure fertilization. Morse also tripped flowers, allowing the stigma to strike the standard. In these experiments, 76 flowers in 1908 produced 18 pods, or 23.7 per cent, and 42 flowers in 1909 produced 22 pods, or 52.4 per cent. These figures are but slightly larger than where the standard was removed. When the stigma was allowed to strike a piece of wood used in tripping, 21 flowers in 1908 produced 3 pods, and 12 flowers produced 4 pods—percentages 14.3 and 33.3, respectively. Though the numbers of flowers used in the last test were small, the results do not indicate that any additional benefit was secured.

The second method was to remove the standard and then sever the keel at the base with a razor. The column thus retained its position in the keel unchanged after tripping. The results of the experiment with this method are shown in Table XV.

TABLE XV.—*The setting of alfalfa pods by flowers when the standard was removed and the keel severed at base.*

Observer.	Place.	Year.	Number of plants.	Number of flowers tripped.	Number of pods formed.	Flowers bearing pods.	Number of seeds.	
							Total.	Average per pod.
						<i>Per cent.</i>		
Westgate.....	Washington, D. C.	1908	13	246	52	21.1	-----	-----
Morse.....	Arlington farm.....	1908	10	120	19	15.9	28	1.4
Do.....	do.....	1909 ¹	6	22	12	54.0	23	1.9
Do.....	do.....	1909 ²	8	27	11	40.8	19	1.7
Evans.....	Pullman, Wash.....	1909	-----	76	13	17.1	-----	-----

¹ Plants screened.² Plants not screened.

The proportion of pods to flowers is in fair agreement with those tripped otherwise. It would seem, therefore, that no importance can be attached to the keel as a passive agent of friction when the column retracts.

ARTIFICIAL AGENCIES EFFECTIVE IN TRIPPING.

Any force giving sufficient pressure on the keel, either laterally or vertically, will result in tripping the flower. This may be accomplished by means of the fingers or even by the hand in grasping an entire cluster or bunch of clusters. Tripping may also be accomplished by means of a stick, straw, or pencil point inserted into the flower and then separating the posterior processes of the wing petals. In order to determine the relative effect of these various means, an experiment was carried out in which tripping was accomplished in the following ways: (1) Each flower tripped with a small piece of wood, (2) with a pencil point, and (3) rolled between the fingers.

The data obtained (Table XVI) show little difference in the effects produced by these various methods of tripping.

TABLE XVI.—*Effect of tripping alfalfa flowers by different mechanical methods, at Arlington farm, Virginia.*

Method of tripping.	Year.	Plant.	Number of flowers.	Number of pods.	Flowers bearing pods.	Number of seeds.	
						Total.	Average per pod.
					<i>Per cent.</i>		
With a small piece of wood.	1908	F. C. I. No. 18.....	21	3	14.2	7	2.3
	1909	F. C. I. No. 1.....	12	4	33.3	5	1.2
With a pencil point..	1908	F. C. I. No. 18.....	76	18	23.7	33	1.8
	1909	F. C. I. No. 1.....	42	22	52.3	38	1.7
By rolling between the thumb and fingers.	1908	F. C. I. No. 18.....	75	40	53.3	71	1.7
	1908	F. C. I. No. 1.....	22	7	31.8	9	1.3
	1909	do.....	43	21	48.8	42	2.0

EFFECT OF AGE OF FLOWERS UPON SUSCEPTIBILITY TO FERTILIZATION.

An experiment by Westgate was performed in one of the green-houses of the United States Department of Agriculture at Washington, D. C., for the purpose of determining whether the age of the flower affects its susceptibility to fertilization. A single plant of Peruvian alfalfa (F. C. I. No. 60) was used in this experiment. A number of young, prime, and old flowers were artificially tripped. For the purpose of comparison, a number of flowers at each stage of development were marked, but not tripped. Table XVII shows the percentage of flowers which produced pods under each method of treatment.

TABLE XVII.—*Pod setting in relation to age of alfalfa flowers when tripped.*

Age.	Number of flowers tripped.	Number of pods formed.	Flowers bearing pods.	Flowers not tripped.	Number of pods formed.	Flowers bearing pods.
			<i>Per cent.</i>			<i>Per cent.</i>
Young flowers	15	7	46.66	18	0	0
Prime flowers	34	17	50.00	33	0	0
Old flowers	81	40	49.38	89	3	3.37

A similar experiment, designed to show at what stages of its development an alfalfa flower may become fertilized and also to throw some light on the question as to how long it may remain capable of fertilization, was conducted at Pullman, Wash., by Evans in 1909. All opened and wilted flowers were removed from a number of racemes on five different plants inclosed in netting tents. On the following day all unopened buds on these racemes were removed, leaving only those flowers which had opened during the preceding 30 hours. As the experiment was carried out in September, when the weather was comparatively cool, the flowers remained fresh and open for a longer period than would have been the case in warmer weather. A number of the flowers on these racemes were tripped each day up to the end of seven days, when the tips of some of the petals were beginning to wilt. The experiment was discontinued at this time because the supply of flowers was exhausted. The number of the flowers that were tripped and the percentage of tripped flowers which produced pods are shown in Table XVIII.

TABLE XVIII.—*Results obtained at Pullman, Wash., in tripping alfalfa flowers at different intervals after blooming.*

Time from opening of flower until tripped.	Number of flowers.	Number of pods formed.	Flowers bearing pods.
			<i>Per cent.</i>
1 day.....	103	28	27.18
2 days.....	69	18	26.08
3 days.....	96	36	37.50
4 days.....	64	21	32.81
5 days.....	79	19	24.05
6 days.....	53	28	52.83
7 days.....	64	16	25.00

A number of flowers were left untripped on these plants. Less than 5 per cent of the untripped flowers produced pods.

The results of both experiments, as tabulated, show that there is no definite relation between the age of the flowers when tripped and the proportion of pods developed. Clearly there is no diminution in the ability of the flowers to become fertilized as long as the flowers remain open.

FORCE NECESSARY FOR TRIPPING.

Burkill's results in measuring the force necessary to trip alfalfa flowers are thus reported:

That the separation of the basal processes is the legitimate and almost only natural method of exploding the flower is obvious from the following consideration. By means of a fine wire hung onto the alæ, weights to a known extent were suspended from them. In September, 1892, flowers obtained near Poulton (Gloucestershire) were found to explode with an average weight of 1.68 grams (maximum and minimum, 2.37 and 0.93). Now, an insect visiting the flower rests its weight on the points whence these weights were hung. The worker of *Apis* I find to weigh about 0.096 and *Bombus hortorum* (large specimens) 0.199 grams. The mere weight of these two insects is therefore quite insufficient to explode the flower. Moreover, the pedicel of the flower bends under a weight insufficient to explode the flower, so that in these experiments I found it necessary always to fix the flower by a wire hooked into the standard; and, again, the hive bee so settles as to hold the parts of the flowers together with its feet.

By the same method of experiment I discovered that the flower is not always in the same degree of explosiveness; the hotter the weather the more explosive is the flower. In cold weather the flower frequently remains unexploded for eight or nine days, after which it withers, but in hot, sunny weather I found three days to be the maximum duration, for explosion is brought about often within 24 hours from the opening of the bud. We must remember in this connection that *M. sativa* is of Persian origin and has only traversed Europe northward by slow degrees.

Shaking by the wind can not explode the flowers. Pieces of paper with a surface of 18½ and 22 square inches were tied to stalks of this plant in order to give more power to the wind, but no effect was observable from the shaking it produced.¹

Table XIX gives the results of experiments carried out by Westgate with an apparatus similar to that used by Burkill. His results confirm those of Burkill in showing that the force required is much greater than the mere weight of bumblebees or other insects which trip alfalfa flowers. They also show clearly that the force required diminishes as the flowers become older. There is also a considerable range of variation in the weight required to trip different flowers of approximately the same age.

¹ Burkill, I. H. On the fertilization of some species of *Medicago* L. in England. Proceedings, Cambridge Philosophical Society, v. 8, pt. 3, p. 146, 1894.

TABLE XIX.—*Weight (in grams) necessary to trip alfalfa flowers on different plants at different stages of maturity.*AT ALMA, NEBR.¹

Plant.	Young flowers.	Prime flowers.	Old flowers.
F. C. I. 138.....	2.14	1.49	0.68
F. C. I. 139.....	3.89	3.37	3.37
M. 1221.....	6.42	3.56	2.60
M. 1222.....	3.37	2.54	1.30
F. C. I. 142.....	7.12	3.69	2.14
Average.....	5.18	2.92	2.07

AT ARLINGTON FARM, VIRGINIA.²

F. C. I. 99.....	6.57	2.22	1.68
S. P. I. 17992.....	2.07	1.49	.33
S. P. I. 21232.....	4.79	3.04	.45
Average.....	4.21	2.33	.77

¹ Experiment performed August 4, 1903. Temperature 98° to 101° F.; humidity very low; bright sun. Number of flowers used in experiment as follows: Young, 16; prime, 22; old, 21.

² Experiment performed July 2, 1908; used one flower at each stage of maturity.

Observations made at different times and places indicate that wind or rain do not ordinarily cause alfalfa flowers to become tripped. Even when blowing with high velocity the wind sways the plants back and forth usually without causing the racemes to strike against adjoining plants. At Chinook, Mont., during a high gale accompanied by a rainstorm, which lasted for a few minutes, a small proportion of a number of flowers that had been marked was tripped. The number of flowers which become tripped through the influence of wind or rain, however, in ordinary seasons is evidently small.

EFFECT OF PARTIAL SHADE.

In conducting the experiments described in this paper it has been observed that on the different plants used those flowers which have been inclosed in the covering made by a single thickness of mosquito bar remain in bloom longer and that the petals seem to be larger than on those flowers which were not inclosed. As it seemed possible that the effect of the slight shade or the breaking of the force of the wind might also influence the development of pods and seed, an experiment was performed at Pullman, Wash., in 1908, to obtain some information in regard to this point.

Several plants were selected, and a portion of each plant was inclosed in a tent made of netting (tarlatan); the remaining portion of each plant was not inclosed, but was protected on three sides and partially from above by one thickness of netting, which was between the plant and the sun and also between the plant and the prevailing winds, yet did not prevent the access of bees and other insects. The results of this experiment are shown in Table XX, in which the results secured on unprotected plants at the same time and place are also presented for the purpose of comparison.

TABLE XX.—*Pods and seeds formed on alfalfa plants at Pullman, Wash., in 1908 under different conditions as regards shade and insect visitation.*

Plant.	Conditions.	Number of flowers.	Number of pods developed.	Flowers bearing pods.	Number of seeds.	
					Total.	Average per pod.
	Flowers open to insects, sun, and wind...	869	207	<i>Per cent.</i> 23.8	574	2.77
No. 03 ...	Shaded by one thickness of netting, insects not excluded.....	160	35	21.8	53	1.51
No. 03-A ...		71	21	29.5	71	3.38
No. 41 ...		112	31	27.6	88	2.83
No. 89 ...		99	22	22.2	43	1.95
No. 89-A ...		71	18	25.3	41	2.27
	Total	513	127		296	
	Average.....			24.7		2.33
No. 03 ...	Entirely inclosed in mosquito netting....	141	14	9.9	19	1.35
No. 03-A ...		99	7	7.0	19	2.71
No. 41 ...		132	4	3.0	5	1.25
No. 89 ...		105	2	1.9	3	1.50
No. 89-A ...		43	0	0	0	0
	Total	520	27		46	
	Average.....			5.1		1.70

As shown in Table XX, 23.8 per cent of the flowers which developed under natural conditions produced pods. The average number of seeds per pod was 2.77. On the stems where the flowers were screened from sun and wind by one thickness of mosquito netting but which were open to the visits of honey-gathering insects, 24.7 per cent of the flowers produced pods, which contained an average number of 2.33 seeds each. On the stems which were entirely inclosed by one thickness of mosquito netting, thus excluding insects, 5.1 per cent of the flowers produced pods, which contained an average number of 1.7 seeds each.

In this experiment the proportion of flowers producing pods and the number of seeds per pod were practically the same when the flowers were screened from sun and wind by one thickness of mosquito netting, which did not exclude insects, as when the flowers developed under natural conditions. It is evident from these results that the shade produced by a covering of one thickness of mosquito netting had in this case no appreciable effect on the setting of pods.

PRACTICAL ASPECTS OF TRIPPING.

The recognition of the efficiency of tripping in the seed setting of alfalfa makes it possible to secure inbred seed whenever cross-pollination is not desired. This can be accomplished by isolating the plants to any degree that is necessary and then tripping, using such artificial means as are called for by the extensiveness of the operations. The observed increase of the seed crop thus obtained indicates the possibility of adopting this method on an extended scale to secure alfalfa-seed crops, especially where the plants are grown in cultivated

rows. It may be practicable to utilize some simple type of machine that will artificially trip alfalfa flowers and thus increase the seed crop. This subject is at present under investigation. Another possibility lies in propagating such bees as are effective pollinators. It might, indeed, be profitable to introduce into the United States the bees that are most effective in the native land of alfalfa.

TRIPPING IN RELATION TO SEED SETTING IN ANNUAL MEDICAGOS.

To determine the relation of tripping by insects to seed setting in the annual medicagos, a number of the species were covered by cages so made as to exclude all but very minute insects and left through the flowering and fruiting period. The species which at Chico, Cal., formed pods readily and apparently as well as in the open are shown in Table XXI.

TABLE XXI.—*Species of annual medicagos readily forming pods under cover of cages.*

Plant designation.	Species.	Plant designation.	Species.
S. P. I. No. 10725.....	<i>Medicago orbicularis</i> .	S. P. I. No. 17783.....	<i>Medicago tuberculata</i> .
S. P. I. No. 19433.....	<i>M. hispida confinis</i> .	S. P. I. No. 26077.....	<i>M. scutellata</i> .
S. P. I. No. 22649.....	<i>M. hispida denticulata</i> .	S. P. I. No. 28790.....	<i>M. tuberculata aculeata</i> .
S. P. I. No. 19449.....	<i>M. turbinata</i> .	S. P. I. No. 9743.....	<i>M. muricata</i> .
S. P. I. No. 19442.....	<i>M. rugosa</i> .		

Whether the flowers in any of these species set seed without tripping can not be stated positively, but so far as could be determined they became tripped before setting seed, and apparently the tripping was automatic. However, this point could not be determined definitely in all cases. The flowers in some of the species have a very short staminal column. This makes it difficult to observe the tripping process as readily as in species with a long staminal column.

In two species (S. P. I. No. 30111, *Medicago ciliaris*, and S. P. I. No. 16874, *Medicago echinus*) pods did not form in as large numbers inside the cages as outside, but even with these a number of pods formed in the cages.

To determine whether artificial tripping is beneficial in *Medicago echinus*, flowers of this species were worked as follows:

Six racemes, containing 28 flowers, were artificially tripped, resulting in three pods forming.

Four racemes, containing 21 flowers, were left untripped as a check, and these set one pod.

The number of racemes rather than the number of flowers should be used as a basis of comparison, as not all of the flowers ever set pods.

In *Medicago echinus* there are five to seven flowers in a cluster, but only one or two burs form from this number, even though all the flowers in a cluster are tripped.

GENERAL CONCLUSIONS.

The numerous researches of previous investigators on the pollination of the alfalfa flower have resulted in somewhat divergent conclusions. In but few cases has any attempt been made to determine the relation of pollination to the resultant crop of seed.

The opinion has prevailed that insect pollinizers are of vital importance and that in the absence of these in adequate numbers the resultant seed crop is necessarily small.

It has, however, been generally recognized that climatic conditions are important, as practically all the commercial seed is raised in regions having a semiarid climate, at least during the time the seed crop is made.

Alfalfa flowers remain fully susceptible to pollination from the time of opening until the petals wither. Pollination is ordinarily effected when the elastic staminal column has become "tripped." No evidence was found to favor Burkill's theory that tripping effects the rupture of the stigmatic cells and that this is an important factor in fertilization. Flowers tripped in various ways to prevent any stimulation or rupturing of the stigma by contact set pods equally as well as those tripped naturally.

Flowers tripped artificially, and therefore self-pollinated, set pods freely. In one series of experiments on 77 plants at 7 different places, 9,074 flowers set 2,784 pods when artificially tripped (a percentage of 30.68), while 8,939 flowers on the same plants exposed to natural conditions set 1,499 pods (16.76 per cent). The pods from artificially tripped flowers contained an average of 1.72 seeds each, while those from naturally tripped flowers averaged 2.22 seeds each.

Pollination from a different flower on the same plant is no more effective than self-pollination, but pollen from another plant increases both the proportion of pods set and the number of seeds per pod. It makes but little difference whether the pollen parent be the same or a different variety.

Tripping in alfalfa flowers may be automatic or may be effected by insects and other external agents. Untripped flowers form pods and seeds only in rare instances. Automatic tripping is a normal phenomenon. On two plants at Chinook, Mont., in 1909, 33 out of 57 marked flowers became automatically tripped on one plant and set 21 pods, and under the same conditions 64 flowers on the second plant produced 16 pods from 36 automatically tripped flowers. The percentage of pods to flowers on the first plant is 36.84 and on the second 25. These are quite as high as normally occur under natural field conditions. In a similar experiment at Pullman, Wash., in 1910, 60 flowers out of 775 on 9 plants became self-tripped, and 21 of these set pods. In this case only 7.74 per cent of the flowers automati-

cally tripped, of which 35 per cent set pods, while under natural conditions the same season 13.15 per cent of the flowers developed pods.

There is a wide range of variability in alfalfa plants as regards the readiness with which the flowers become tripped, either automatically or by the aid of external objects, and also in their ability to set fruit when tripped. The number of pods set is not proportional to the number of flowers, as a smaller proportion of pods is produced on many-flowered racemes than on few-flowered racemes.

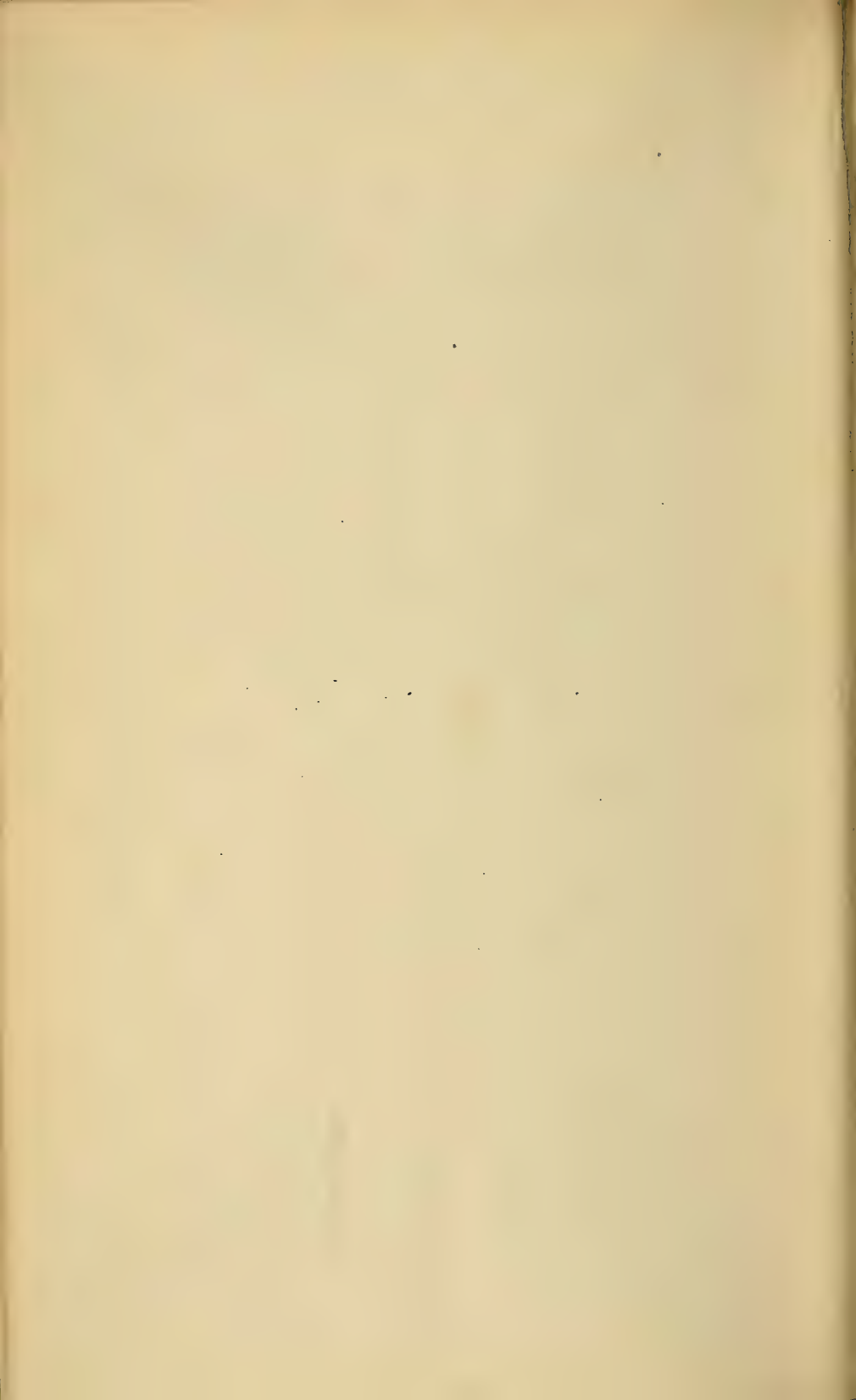
Automatic tripping takes place most frequently in hot sunshine. Humidity is doubtless also a factor. Automatic tripping can readily be observed by focusing a burning glass on open flowers or by simply bringing shaded flowers into the sunshine on a hot day.

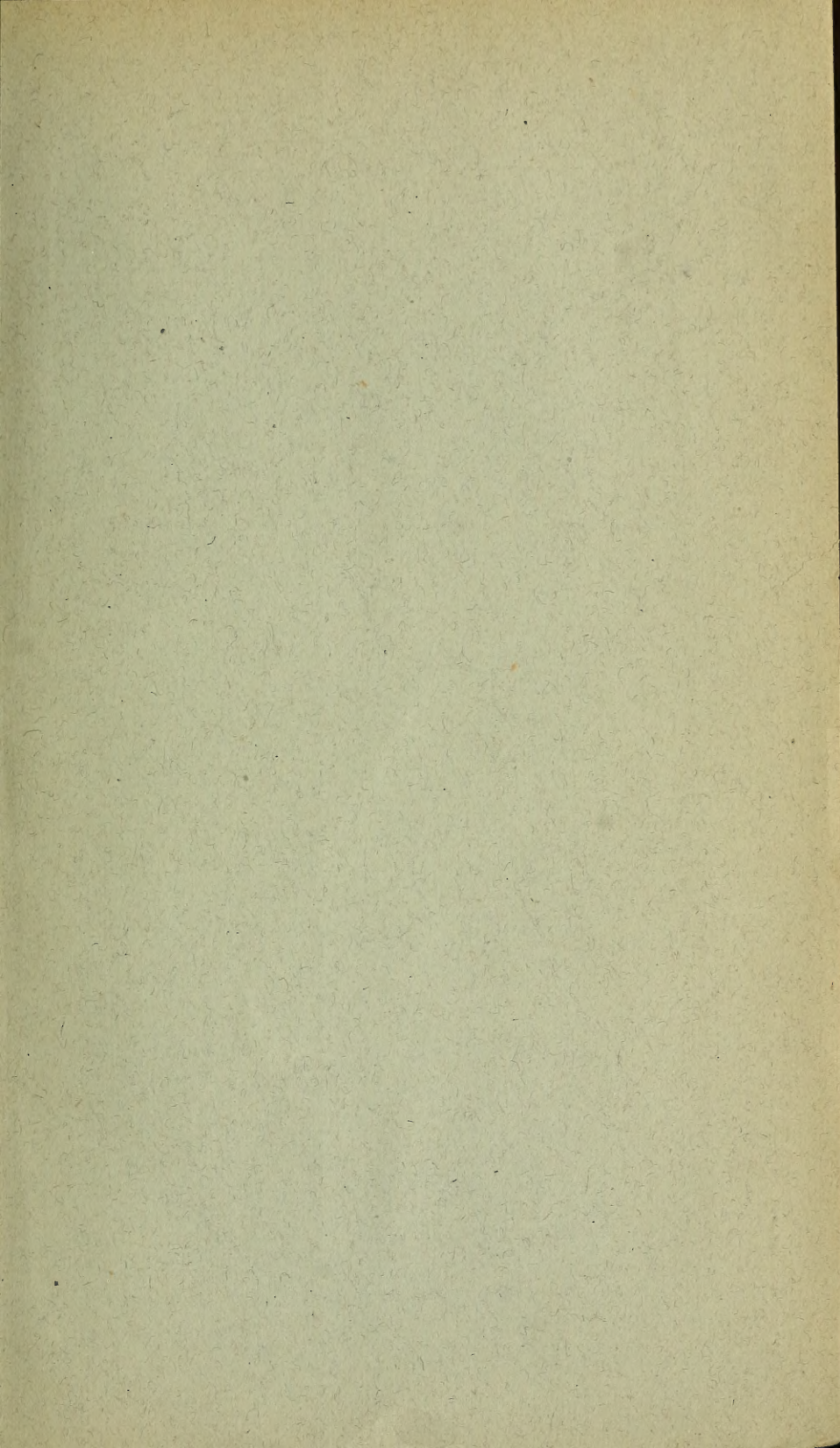
Insects are the natural agents of cross-pollination in alfalfa, but even where they are scarce, good crops of seed may be produced. Bumblebees and leaf-cutting bees (*Megachile*) are the most efficient insects to trip alfalfa flowers. Honeybees secure much honey from alfalfa flowers, but trip only a very small percentage of the blossoms. Night-flying insects are of negligible value. Butterflies have never been observed to trip a flower during the course of these studies.

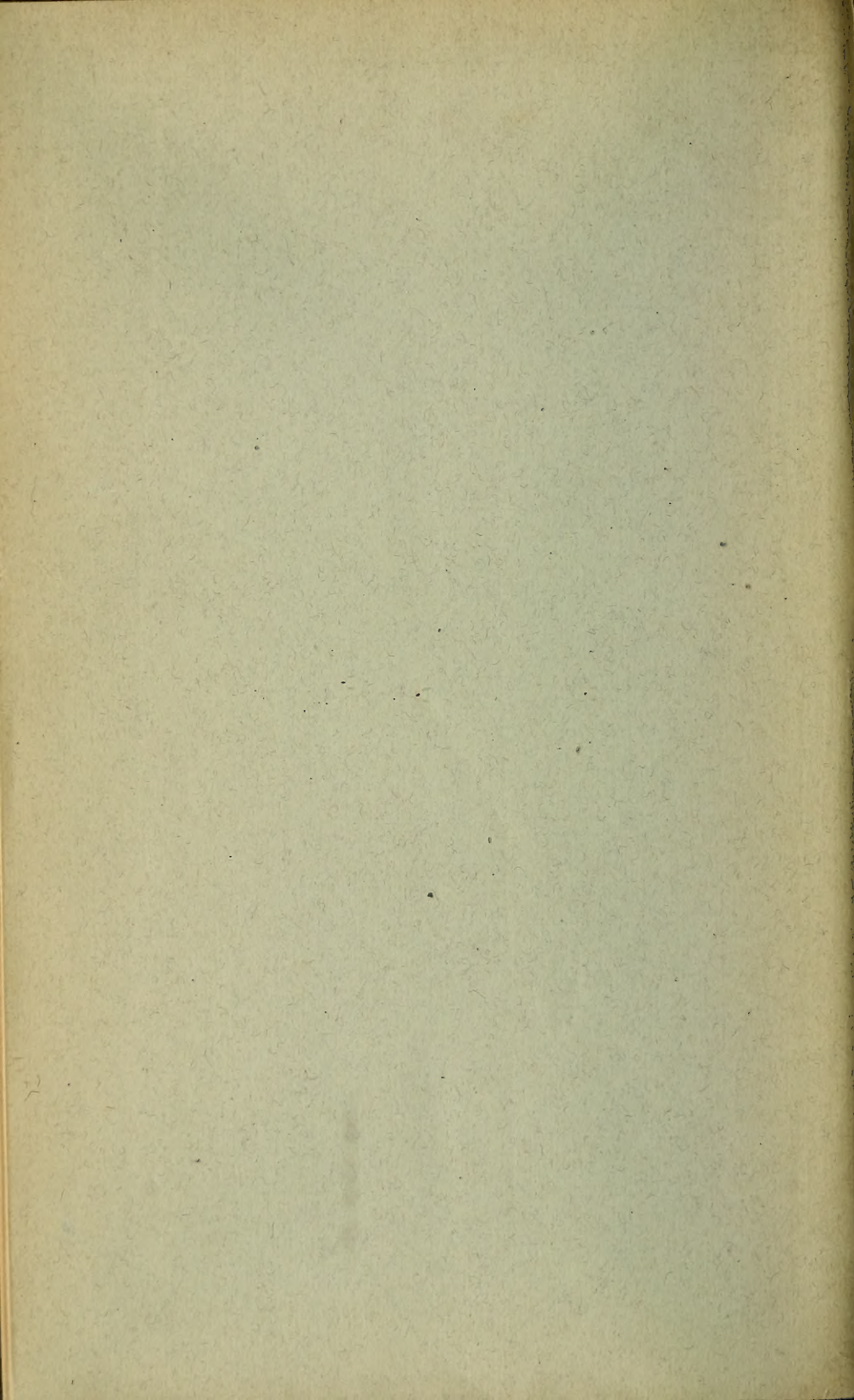
Rain or wind causes but few alfalfa flowers to become tripped.

Automatic tripping with consequent self-pollination probably results in the setting of as many pods as does tripping by insect visitors, at least in the West. This conclusion is also in accord with the observation that excellent seed crops are produced in sections where bumblebees and other insects capable of tripping alfalfa flowers are decidedly scarce.









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